THE EFFECTS OF CONCURRENT TRAINING ON PERFORMANCE VARIABLES IN PREVIOUSLY UNTRAINED MALES

A Thesis

by

SHAWN PHILIP GLOWACKI

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2003

Major Subject: Kinesiology

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Approved as to style and content by:

Stephen F. Crouse (Chair of Committee)	Robert B. Armstrong (Member)
Jerome Congleton (Member)	Steve Dorman (Head of Department)

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ABSTRACT

The Effects of Concurrent Training on Performance Variables in Previously Untrained Males. (December 2003)

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Research has shown conflicting results involving interference of strength development with combined resistance and endurance training. **Purpose:** To examine if endurance training and resistance training performed concurrently would produce different performance and physiological results when compared to each type of training alone. **Methods:** Forty-five untrained males were recruited and randomly assigned to one of three 12 wk training groups. An endurance training (ET, N=12) group trained by running (2-3 days/week, 20-40 min, 65- 80% HRR), a resistance training (RT, N=13) group performed a resistance training program (2-3 days/week, 3 sets/8 exercises, 6-10 reps, 75-85% 1RM), and a concurrent training (CT, N=16) group performed both the endurance and resistance training programs (5 days/week, even # week 3 endurance/2 resistance workouts, odd # week 3 resistance/2 endurance workouts). All groups were tested for all the following variables prior to and following training: percent body fat, VO_{2max}, isokinetic-maximal torque and avg. power at two speeds, 1RM leg press, 1 RM bench press, vertical jump, lower body power (as calculated by the Lewis formula) and 40-yard dash time. **Results:** Percent body fat was significantly ($p \leq .05$) decreased in both the ET and CT groups. Only the ET group significantly improved VO_{2max} (+8.24%). Minimal changes were found for any of the isokinetic measurements. The ET, RT, and CT groups demonstrated significant improvements in leg press (20.4, 40.8, and 39.4%) and bench press (7.5, 30.5 and 21.2%) 1 RM. RT and CT 1 RM improvements were similar and significantly greater than the ET group. Only the RT group significantly increased power. No group showed a significant change in vertical jump or 40-yard dash time. **Conclusions:** Findings indicate that endurance training does not interfere with strength development, but resistance training appears to hinder development of maximal aerobic capacity.

DEDICATION

To my parents, Curt and Kris, who have supported me in so many ways throughout my education.

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Last of all, I would like to thank Wade Womack for his ability to make me laugh through the most frustrating situations, and my parents for their love and support. Thank you.

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CHAPTER I

INTRODUCTION

Many people, both athletes and non-athletes, take part in a combination of resistance and endurance training, which is often called concurrent training. These people are expecting to experience the benefits that these two different types of training have to offer. A number of studies have shown that performing these two types of training simultaneously can be detrimental to the gains that might be made in performing one type of training alone (6,7,12,14,20,22,25). In contrast, numerous studies have reported that there is no interference in performance gains with concurrent training when compared to resistance or endurance training alone (1,5,6,18,23,27,28,29,32,36).

The inconsistent and conflicting results of the published research examining the effects of concurrent training present a problem for athletes and non-athletes alike. The problem is whether or not the benefits of resistance and endurance training are mutually exclusive. For example, certain sports such as soccer and basketball have both anaerobic and aerobic components (3). It would be beneficial to know if the anaerobic training in which these athletes engage is being negatively affected by any aerobic training in which they might participate. For the non-athlete training to increase strength and to optimize their time spent working out, it would help to know if he or she is compromising strength gains by adding endurance training to his or her workout.

This thesis follows the style and format of *Medicine & Science in Sports & Exercise*.

The adaptations of skeletal muscle induced by resistance and endurance training are generally specific and are at times opposing (33,34). Adaptations to training generally follow the principle of specificity, which states that specific exercise elicits specific adaptations, creating specific training effects (3,9,30). Resistance training results in increased force production, hypertrophy of muscle fibers, increased glycolytic enzyme activity, increased intracellular ATP and phosphocreatine stores, and a reduction of mitochondrial and possibly capillary density (3,9,34). Resistance training adaptations, such as decreases in capillary and mitochondrial density, could impede endurance capacity (29,32). In addition, resistance training has been shown to have little effect on maximal oxygen consumption (VO_{2max}) (9,18,34).

The adaptations seen with endurance training include an increase in each of the following: mitochondrial and capillary density, enzymes of the TCA cycle and electron transport chain, myoglobin, and $V0_{2max}$ (3,9,34). Endurance training has been associated with a decrease in muscle fiber size (25,32,34). Due to the fact that force production is highly correlated with cross sectional area of a muscle, this decrease in muscle fiber size would likely result in a decrease in strength. Since it is known that the adaptations to training are very specific to the type of training, and that endurance and resistance training clearly cause different adaptations, it seems reasonable that some attenuation of the adaptations caused by one or both of these types of training might occur when they are conducted simultaneously.

Purpose of Study

The purpose of this study was to examine whether or not endurance training and resistance training performed concurrently would produce different performance and physiological results when compared to resistance or endurance training alone.

Null Hypotheses

The *a priori* null hypotheses for this investigation were as follows:

1. There will be no difference in strength changes among the three groups after training.
2. There will be no difference in power changes among the three groups after training.
3. There will be no difference in maximal oxygen consumption among the three groups after training.

Rational for Hypotheses

Hypothesis 1

The primary purpose of this study was to determine whether or not concurrent resistance and endurance training would produce attenuated strength gains when compared to resistance training alone. Many studies have shown that concurrent training can interfere with strength gains when compared to resistance training alone (6,7,12,14,20,22,25). However, a slightly larger number of studies have shown no interference in strength gains (1,5,6,17,18,23,27,28,29,32,36). Hunter et al. (23) conducted a twelve week study using a similar training program to the program used in this investigation and found similar changes in maximum squat and bench press in the resistance training only and the concurrent training groups. Based on the findings of these studies and the training protocols used in this investigation it was anticipated that the concurrent group and resistance training only group would make similar gains in the traditional test of maximum strength (one repetition maximum leg press and bench press). However, it was anticipated that any gains in maximum strength for the endurance only group would be much less than those seen in the resistance training only and concurrent training groups.

Hypothesis 2

Several studies examining the effects of simultaneous resistance and endurance training have shown that those who only resistance train make greater lower-body power gains than those who concurrently train (14,23,20,25). Two of these studies found that subjects who only resistance trained made greater gains in vertical jump than those that concurrently trained (20,23). One of these three studies was the study by Hunter et al. (23) that, as previously stated, used a similar training program to this investigation. Similarly, Dudley and Djamil (14) showed that the concurrent and resistance only groups had similar maximum isokinetic knee-extension torque improvements at low velocities (0 - 96.3 deg/sec), but the groups differed at the higher velocities (96.3 - 240 deg/sec). Kraemer et al. (25) reported that after twelve weeks of training lower body power, measured by the Wingate anaerobic test, was increased solely in the group that performed only resistance training. Research has also shown endurance training alone to be associated with suppressed vertical jumping ability (power) (34). From these findings it was expected that the resistance training only group would make greater lower-body power gains than the concurrent and endurance only groups.

Hypothesis 3

Studies that have been conducted examining the effects of concurrent training for strength and endurance have shown the gains in endurance performance (maximal oxygen consumption, VO_{2max}) to be similar to that of endurance training alone (1,7,8,14,18,20,21,22,23,25,32,36). Nelson et al. (29) did find that VO_{2max} gains were compromised during the second half of twenty weeks of training in the concurrent group. However, studies showing that concurrent and endurance only groups made similar gains in VO_{2max} vastly out number this single finding. Research has also shown that resistance training alone has little effect on VO_{2max} (34). In this investigation it was expected that the group that concurrently trained and the group that only endurance trained would make equal improvements in VO_{2max}, and that these improvements would be larger than any seen in the resistance training only group.

Delimitations

The investigation was delimited to the following:

1. Apparently healthy men.
2. Subjects between 18 and 40 years of age.
3. Subjects who had not regularly resistance or endurance trained for at least 3 months prior to the start of the study.
4. Subjects being randomly placed in one of three training groups prior to pre-testing.
5. Three defined training groups:
    a) Endurance Training Only (2 or 3 days/week of running)
    b) Resistance Training Only (2 or 3 days/week of resistance training)

c) Concurrent Training (5 days/week alternating endurance and resistance training sessions)

6. The measurement of body weight, maximal oxygen consumption, percent body fat, one repetition maximum leg press and bench press, vertical jump, forty-yard dash time, peak torque and average power at 60 degrees/second, and peak torque and average power at 180 degrees/second during flexion and extension as dependent variables.
7. Residual volumes used in calculating body composition were estimated.

Limitations

This investigation was limited by the following:

1. Findings are specific to apparently healthy, untrained males age 18-40.
2. Self selection of subjects to enter the study.
3. Self reported diet records.
4. Self reported activity records.
5. Self reported untrained status for 3 months prior to study.
6. Self reported abstinence of any type of exercise-training not prescribed as part of group dependent training.
7. Subject compliance.

Significance of Study

Many studies have been conducted examining the effects of simultaneous resistance and endurance training on a variety of physiological and performance factors. This research has shown inconclusive results as to whether or not performing endurance and resistance training together can interfere with strength or endurance gains when compared to one type of training alone. This study was designed to examine the effects of engaging in a basic endurance training and/or resistance-training program on various performance variables. The training programs used in this investigation are similar to those recommended by the American College of Sports Medicine that are prescribed to increase physical fitness around the world. The information gained from this study will allow researchers, clinicians, strength and conditioning coaches, and personal trainers to better prescribe exercise to their patients, athletes, or clients.

Review of Literature

Introduction

Several different types of studies have been conducted examining the effects of concurrent training. Some studies have examined whether or not concurrent training produces different results than either resistance or endurance training alone. Other studies have investigated the effects of adding resistance training to the training regime of endurance-trained athletes. These studies have examined how endurance performance was affected. The studies are often similar in some aspects of their design but are very different in others. The break down of subject training groups is almost identical for all studies. Most studies include an endurance training only group, a resistance training only group, and a concurrent training group. Some studies have included a control group. Kraemer and associates (25) studied a concurrent group as well as a concurrent group that did only upper body resistance training. The studies examining the effects of resistance training on endurance performance differ slightly, in that they normally do not have a resistance training only group. Other aspects of the studies investigating the effects of concurrent training differ greatly. These aspects include the modality of resistance training, the modality and duration of endurance training, when each training session was performed within concurrent training, the volume of training by each group, the training status of subjects prior to training, subject gender, and the types of performance/physiological testing.

Research Findings

Concurrent training studies examining the idea that endurance training is detrimental to strength gains have shown inconsistent results. Hickson et al. (22) were among the first to investigate concurrent training in 1980. In this study the resistance training only group increased their force production, as measured by one repetition parallel squat, by a statistically significant greater amount than did the concurrent group. These results brought about the idea of an "interference phenomenon," the concept that endurance training inhibits strength development. A study by Dudley and Djamil (14) showed slightly different results. This study showed that the concurrent and resistance training only groups had similar improvements in maximal-isokinetic knee extension torque at low velocities (0 - 96.3 deg/sec). However, the groups differed in their maximum torque production at higher velocities (96.3 - 240 deg/sec) (14). Studies by Hennessy et al. (20) and Craig et al. (12) involving concurrent training showed that upper body strength gains were not compromised with concurrent training, but lower body strength gains were. In these two investigations lower body strength was measured by one repetition squat and leg press, respectively. Hennessy et al. also found that only the resistance training group made significant improvements in twenty-meter sprint time and vertical jump. The concurrent group showed no change in these measurements (20). In

1987 Hunter et al. (23) reported similar results involving vertical jump with the resistance training group increasing by a much larger percent than the concurrent group. However, it is interesting to note that in this study the two groups showed no statistically significant difference in improvements in lower or upper body strength.

Kraemer and associates (25) reported that concurrent training interfered with leg press and double leg extension strength development. This study also showed that only the resistance trained group improved in peak and mean power during the Wingate anaerobic test. Bell et al. (6) reported interference in strength gains in the subjects of the concurrent group who were female, but not in the male subjects. Another study by Bell and associates (7) found the resistance training group to make larger gains in knee extension one repetition maximum (1 RM), but not leg press 1 RM when compared to the concurrent group. A very recent study conducted by Balabinis et al. (4) showed that the resistance training group made greater gains in leg press and bench press 1 RM compared to the concurrent group. However, interestingly the concurrent group in this study showed greater improvements in many of the other performance tests conducted. It should also be noted that in all but one of the above studies changes in $V0_{2max}$ were the same for the concurrent and endurance only groups (4).

Based on the findings of the studies discussed in the two previous paragraphs it seems rather convincing that endurance training interferes with strength development. However, several studies have been conducted showing no interference in strength development by concurrent training (1,5,6,18,23,27,28,29,32,36). Sale et al. (32) found no interference in strength or endurance development with concurrent training. This study actually showed that the concurrent group improved the most in the number of repetitions performed at 80% of leg press 1 RM. These results may have been due to the hybrid nature of the training program (endurance training = 3 minute bouts at 90-100% VO_{2max} and resistance training = sets of 15-20 repetitions) used in this study. Abernethy and Quigley (1) performed a study solely examining concurrent training in elbow extensor muscles. Their study also showed no interference in strength development. Four other studies have also reported no difference in the strength gains of the concurrent and resistance training only groups (15,18,27,29). One of these studies also showed the improvements in vertical jump to be slightly greater in the concurrent group (27). Another showed no difference in performance of the Wingate power test (18).

Balbinis et al. (4) actually found the concurrent group to improve more than the resistance training group in Wingate power. It is interesting to note that in this study the resistance only group out-performed the concurrent group in 1 RM leg press and bench press, but the concurrent group showed greater improvements in 1 RM squat, vertical jump, and Wingate power (4). As previously stated, Hunter et al. (23) showed interference in vertical jump performance when comparing untrained subjects who concurrently trained to those who only resistance trained. However, they failed to show any interference when a group of trained runners who began resistance training was compared to the untrained group who only resistance trained. A recent study conducted by McCarthy and associates also reported no strength impairments with concurrent training (28).

A small number of other studies have examined whether or not adding resistance training to the training regimen of endurance-trained athletes could improve their endurance performance. The results of these studies are also inconsistent. Bishop and

Jenkins (8) showed that resistance training of endurance-trained cyclists did not improve their performance. In this study the resistance trained subjects did improve in the strength test, but showed no difference from the control group in average power output during a 1-h cycle test, lactate threshold, or $V0_{2max}$. Nelson et al. (29) reported that after 11 weeks concurrent training actually interfered with gains in $V0_{2max}$ as compared to endurance training alone. Here the authors speculated that as a result of hypertrophy a dilution in mitochondrial volume of the type IIa fibers might have occurred in the concurrent group.

Hickson and associates (21) performed a study showing just the opposite of Nelson’s findings. They found that subjects who had resistance trained showed greater improvements in short and long-term endurance compared to those who only endurance trained. Short-term endurance was 5-8 min to exhaustion and long term was maximal cycling time to exhaustion at 80% VO_{2max}. It was hypothesized that resistance training increased short-term endurance performance by increasing high-energy phosphate and glycogen stores. Short-term endurance may have also been improved by increases in the fast twitch to slow twitch fiber area ratio. Long-term endurance performance was believed to have increased due to a delay in the recruitment of fast twitch fibers as a result of resistance training increasing maximum strength (21). It has also been suggested that long-term endurance performance can benefit from resistance training not only by reducing large motor unit recruitment, but also by improving running or cycling economy (34). Similar to Hickson’s findings, Balabinis et al. (4) recently reported that those who concurrently trained made greater gains in VO_{2max} than those who only endurance trained. A summary of the reviewed concurrent studies, their training modalities, and their findings are listed in table 1.

TABLE 1. Literature findings.

Author	**Training Routine**	**Findings**
Abernethy & Quigley (1)	7 weeks of training 3 days per week S group: 2 sets of 30sec isokinetic elbow extensions E group: interval arm cranking of 5x5 min bouts at 40-100% $V0_{2max}$ C group: S and E on alternating days	No interference in S development $V0_{2max}$ E=C group
Balabinis et al. (4)	7 weeks of training 4 days/week S group: 1-5 sets of 3-8 reps at 40-95% of 1 RM for 4 exercises E group: 4 days running varying % of max HR C group: Both S and E on same day, E before S	S group > increase in 1 RM leg press and 1 RM bench press C group > increase in 1RM squat, lat. pull down, vertical jump, and Wingate power C group > increase in VO2 than E group
Bell et al. (5)	12 weeks S group: 3 times per week circuit fashion workout on hydraulic equipment E group: 3 times per week, continuous rowing, 40-55min at 85-90% max HR C group: Both E and S	S increases were = for S and C group
Bell et al. (6)	16 weeks of training 3 days/week S group: 3-6 sets of 2-10 reps at 65-85% of 1 RM for 7 exercises C group: S and 2 days 30+ min continuous rowing at VT/1 day 5 sets x 3 min at 90% VO2 max	S increase were > for the women in the S group. S increase = for men in C and S groups
Bell et al. (7)	12 weeks of training 3 days/week S group: 2-6 sets of 4-12 reps at 72-84% of 1 RM for 8 exercises E group: 2 days continuous cycling at VT for 30-42 min & 1 day interval training (4-7 3 min bouts at 90% VO2 max) C group: Both S and E on alternating days	S increase were > for the S group in knee ext. $V0_{2max}$ E=C group
Bishop et al. (8)	12 weeks of training E group: cycling C group: E + 5 sets of parallel squat to failure 3 times per week	VO2max, lactate threshold, and endurance performance = for E and C group Increase in 1RM squat > C group
Craig et al. (12)	10 weeks of training E group: 30-35 minutes of running 3 times per week at 75% max HR S group: 3 sets of 8-10 reps at 75 % of 1RM 3 times per week C group: Both E and S, E before S	Lower but not upper body S compromised in C group $V0_{2max}$ E=C group

TABLE 1. Continued.

Dudley & Djamil (14)	7 weeks training 3 days/week S group: 2 sets of 30-sec isokinetic knee ext. 4.19rad*s-1 E group: interval cycling of 5x5min. bouts of 40-100% $V0_{2max}$ C group: S and E on alternate days	S group increased peak torque up to training speed (4.19rad*s-1); C group increased peak torque up to 1.68rad*s-1 $V0_{2max}$ E=C group
Gravelle & Blessing (18)	11 weeks of training 3days/week S group: 2-4 sets of 10 reps of 5-6 lower body exercise E group: rowing for 45min at 70% $V0_{2max}$ C group: Both S and E, some subjects did S then E others did E then S	Increases in 1RM leg press = for S and C group No difference in Wingate power performance in S and C group $V0_{2max}$ E=C group
Hennesy and Watson (20)	8 weeks of training S group: 3 days per week at 70-105% 1RM E group: 4 days per week running C group: 5 days per week, S and E same da $V0_{2max}$ E=C group y twice a week, 1 day S only, and 2 days E only	Lower but not upper body strength compromised; S group improved 20m sprint and vertical jump and C group did not $V0_{2max}$ E=C group
Hickson et al. (22)	10 weeks training 5 days per week S group: multiple sets of 5 repetitions at > 80% 1RM E group: high intensity cycling and running C group: both S and E	S group increased strength by a greater margin the C group $V0_{2max}$ E=C group
Hickson et al. (21)	10 weeks of training E group: 3-6 days per week of running and cycling C group: E and 4 lower body exercise with 3-5 sets of 5 reps	$V0_{2max}$ E=C group C group improvement was greater than the E group for short term endurance (4-8min) and long term endurance (71-85min cycling and 10km run)
Hunter et al. (23)	12 weeks 4 S and/or 4 E sessions per week C group trained S followed by E S group: 3 sets of 7-10 reps, upper and lower body E group: running 75% HRR for 20-40 min.	C=S group in 1RM for squat and bench press, but vertical jump increases were greater for S group than C group $V0_{2max}$ E=C group
Kraemer et al. (25)	12 weeks of training C group: 4 days per week S and E same day E group: running at 80-100% $V0_{2max}$ S group: heavy/light spilt routine, 3x10RM and 5x5RM	1 RM S was inhibited in the C group for leg press and double leg extension Only S group increased Wingate performance $V0_{2max}$ E=C group
McCarthy et al. (27)	10 week of training 3 days per week S group: 3 sets of 6 reps, 6RM E group: cycling 50 min at 70% HRR C group: S and E on same day	Increases in 1RM squat and bench, vertical jump, isometric knee torque = for S and C group $V0_{2max}$ E=C group
McCarthy et al. (28)	10 weeks training 3 days/week S group: 3 sets of 6 reps of 8 exercises E group: Cycling 50 min at 70% HRR C group: Both E and S on same day alternating order	S increase = for C and S group

TABLE 1. Continued.

Nelson et al. (29)	20 weeks, 4 times per week, S before E S group: 3 sets of 6 reps, isokinetic knee extension, .52rad*s-1 E group: Cycling 30-60 min at 75-85% HR max C group: Both S and E	S increases = for C and S group V02 max gains compromised for the second half of training in the C group
Sale et al. (32)	22 weeks, 2 groups: S one leg and C the other; E one leg and C the other S group: 3 times per week, 6 sets of 15-20 reps on leg press E group: 3 times per week, 5x3min cycle ergometer bouts at 90-100% $V0_{2max}$	No interference with the development of S or E: max reps a 80% of 1RM improved most for C group $V0_{2max}$ E=S+E group
Wood et al. (36)	12 weeks, 3 times per week S group: 1-2 sets of 8-15 reps of 8 exercises E group: 20-45 minutes of cycling or running/walking C group: Both S and E on the same day	No interference with the development of S or E in the C group.

E = endurance; S = strength; C = concurrent

Proposed Mechanisms of Interference

Many of the concurrent studies that have been conducted have shown interference in strength development. However, very few of the authors have attempted to explain why this interference in strength development occurs. Several possible mechanisms have been suggested. These include overtraining, muscle fiber type transformations, muscle fiber hypertrophy, endocrine changes, and changes in motor unit recruitment.

1. Overtraining

Overtraining has been suggested as a mechanism for the decreased strength gains of concurrent training (15). This mechanism is hypothesized due to the fact that in most studies the concurrent group does both the resistance program and the endurance program. It is believed that since the concurrent group is doing a much greater volume of work than the resistance training group, they may become over-trained by the time of performance testing (15). However, if concurrent training caused overtraining then both strength and endurance performance measures would be inhibited when compared to each form of training alone. This inhibition of both strength and endurance performance has not been observed in any of the reviewed literature. However, studies showing that concurrent training results in an increased level of cortisol, an indictor of overtraining, support overtraining as a possible mechanism for attenuated strength gains with concurrent training (6,7,25). Dudley and Djamil (14) demonstrated that overtraining was most likely not responsible for the inhibited strength gains associated with concurrent training. In this investigation very low volumes were used for both the resistance and endurance training programs, but their results still showed interference in strength development of the concurrent group. Moreover, Hennessy et al. (20) regularly monitored subjects for overtraining effects, and reported that within the concurrent group no signs of these were evident. Once again, this investigation showed interference of strength development within the concurrent group.

2. Muscle Fiber Type Transformation

Another proposed hypothesis is that the changes in muscle fiber type associated with concurrent training are different than those of resistance training alone (26). Several concurrent training studies have examined fiber type transformations (7,25,28,29,32). All of these studies have shown little difference in the changes in fiber type transformations of the concurrent groups and the resistance training groups. The changing of fast twitch IIx fibers to fast twitch IIa fibers typically seen with resistance training was also seen in the concurrent groups (25). Most of these studies used histochemical techniques to identify fiber type changes. This technique may have allowed subtle training induced changes in myosin heavy chain characteristics to go unnoticed (26).

3. Muscle Fiber Hypertrophy

Resistance training has been shown to increase the cross-sectional area of skeletal muscle. The amount of force a muscle can generate has been shown to directly relate to muscle fiber diameter or cross-sectional area (3,33). Controversy exists over whether or not endurance training causes any muscle fiber hypertrophy. If endurance training does cause hypertrophy, there appears to be no distinct pattern of hypertrophy (26). It is believed that concurrent training disrupts the pattern of muscle fiber hypertrophy seen when only resistance training is performed (25,29). Kraemer (25) supported this hypothesis by showing that resistance training alone caused hypertrophy of slow twitch fibers and both types of fast twitch fibers. However, the concurrent group only experienced hypertrophy in fast twitch type IIa fibers (25). Likewise, Bell et al. (7) reported no hypertrophy in the type I fibers of the concurrent group. Contrary to these findings Nelson et al. (29) reported that the resistance training group only showed hypertrophy of type II fibers, whereas the concurrent and endurance groups experienced hypertrophy of both type I and II fibers. In the most recent study conducted by McCarthy et al. (28) hypertrophy was shown to be the same for all fiber types in both the concurrent and resistance training groups.

4. Endocrine Changes

Resistance training is normally associated with an increase in testosterone levels, as well as an increase in the ratio of testosterone to cortisol (25,26). These changes lead to an anabolic environment in the body. It has been hypothesized that the endurance aspect of concurrent training could shift this environment to a more catabolic state (6,25,26). Kraemer et al. (25) showed that both the resistance training and concurrent groups experienced an increase in testosterone levels. However, the resistance training group was the only group to increase the ratio of testosterone to cortisol levels. Bell et al. (6) found that concurrent exercise led to higher cortisol levels during the latter stages of training. Likewise, Bell et al. (7) again showed that the women in the concurrent group showed a significant increase in urinary cortisol levels. While an increased catabolic state seems like a very possible mechanism, few studies have investigated endocrine responses, and those that did never reported decreases in testosterone levels with concurrent training (6,7,25,26). In addition, Craig et al. (12) showed that after 10 weeks of training the growth hormone response to a single bout of exercise was the same for both the resistance training and concurrent groups.

5. Motor Unit Recruitment

It has been proposed that concurrent training may alter motor unit recruitment patterns associated with maximal voluntary contractions (26). Endurance training has been shown to decrease vertical jump, and several of the concurrent training studies found the strength only group to make greater gains in vertical jump than the concurrent group (20,23,26,34). This may be due to the endurance training aspect of concurrent training causing a reduction in the capability of the neuromuscular system to rapidly generate force (26). Dudley and Djamil (14) supported this by showing that the resistance-trained group was able to increase force production at high speeds, and the concurrent group only increased strength at low speeds. McCarthy et al. (28) was recently the first to investigate changes in neural activation with concurrent training. The results of this study showed, through the use of EMG, that the amount of neural activation at a given torque was the same after concurrent and resistance training alone.

Further studies are needed examining neural activation; however, changes in motor unit recruitment could be at least partly responsible for inhibited strength gains when muscle fiber changes are the same.

6. Residual Fatigue

In some cases it has been thought that the fatigue from the endurance aspect of the concurrent training may acutely compromise the amount of force that can be produced during the resistance portion of the training (12,14,15). In studies where the endurance training is performed immediately before the resistance training there may be some residual fatigue carried over to the resistance training session. Craig et al. (12) showed that lower body strength, but not upper body was inhibited when running was done before strength training. Here it was suggested that it was the schedule of training responsible for the interference in lower body strength. Sale et al. (32) found that when the endurance and resistance training were performed on alternating days the strength gains were greater than when they were done on the same day. However, interference of strength gains has also been reported when concurrent training was done with endurance and resistance training performed on alternating days (7,14). In the study conducted by Gravelle and Blessing (18) there were two concurrent groups, one which performed endurance training then resistance training and one which did the opposite. In this study both groups showed similar strength gains and no effects of residual fatigue.

While each of these mechanisms may play a role in the interference of strength development with concurrent training there is very little data to support any one of them.

More research is needed to determine if interference does truly exist and if it does what the exact mechanism might be.

Conclusions

Much more research is needed before any definite statements can be made regarding the effects that resistance and endurance training have on each other. There is a substantial amount of evidence that concurrent training has a negative effect on gains of strength and power. In contrast, there are numerous studies that show that concurrent training has no effect on strength gains. Due to the vastly different methodology within the current research it is difficult to compare results across studies. One conclusion that can be drawn is that athletes who are solely concerned with strength and power should probably keep their endurance training to a minimum. Another conclusion that can be made based on the literature that examined the effects resistance training had on endurance performance is that if an endurance athlete adds resistance training it will probably have a positive affect on their performance. All athletes would be best advised to follow the principle of specificity, which means performing training that is specific to the types of movements and energy systems used in their respective sports. For the average person who is training for health benefits, performing concurrent training is probably the best way to improve their physical fitness from a cardiovascular and muscular standpoint.

More research is needed investigating the interaction of resistance and endurance training using the types of training programs that are prescribed by organizations such as American College of Sports Medicine (ACSM). Very few of the studies reviewed have combined resistance and endurance training programs analogous to those recommended by ACSM. These basic programs are the type of exercise regimens that countless people engage in to increase their level of physical conditioning, as well as their performance. Research examining these types of programs would allow the organizations and individuals that prescribe exercise around the world to better understand the consequences of prescribing endurance and resistance training simultaneously.

CHAPTER II

THE EFFECTS OF CONCURRENT TRAINING

Introduction

Many people, athletes and non-athletes, take part in a combination of resistance and endurance training. This type of training is often called concurrent training. These people are expecting to experience the benefits that these two different types of training have to offer. A number of studies have shown that performing these two types of training simultaneously can be detrimental to the gains that might be made in performing one type of training alone (6,7,12,14,20,22,25). In contrast, numerous studies have reported that there is no interference in performance gains with concurrent training when compared to resistance or endurance training alone (1,5,6,18,23,27,28,29,32,36).

The physical adaptations that occur as a result of resistance training, defined as high resistance, low repetition exercise aiming to increase strength, and endurance training, defined as low resistance, high repetition exercise aiming to increase maximal oxygen uptake, are generally different and at times opposed to each other (34). Resistance training results in increased force production, hypertrophy of muscle fibers, increased glycolytic enzyme activity, increased intracellular ATP and phosphocreatine stores, and a reduction of mitochondrial and possibly capillary density (3,9,34). Resistance training adaptations, such as decreases in capillary and mitochondrial density, could impede endurance capacity (29,32). In addition, resistance training has been shown to have little effect on maximal oxygen consumption (VO_{2max}) (18,34).

The adaptations reported to occur with endurance training include an increase in each of the following: mitochondrial and capillary density, enzymes of the TCA cycle and electron transport chain, myoglobin, and $V0_{2max}$ (3,9,34). Endurance training has been associated with a decrease in muscle fiber size (25,32,34). Due to the fact that force production is highly correlated with cross sectional area of a muscle this decrease in muscle fiber size would likely result in a decrease in strength. Since it is known that the adaptations to training are very specific to the type of training performed, and that many people participate in some form of concurrent training, it is important to determine whether or not adaptations that generally accompany endurance and resistance training performed alone will be impacted by concurrent training.

In 1980 Hickson et al. (22) was the first to examine the consequences of combining resistance and endurance training. It was this study that brought about the idea of an "interference phenomenon," the concept that somehow endurance training interferes with strength gains when the two types of training are performed simultaneously. Since then, several studies have been published that corroborate the findings of Hickson et al. (6,7,12,14,20,25). For example, Kraemer et al. (25) reported that a group that only resistance trained made greater improvements in maximum leg press, maximum double-leg extension, and lower-body power output compared to a group that concurrently trained. However, numerous other studies have shown no interference in strength gains when concurrent training was compared to resistance training alone (1,5,6,18,23,27,28,29,32,36). Sale et al. (32) actually found the group that concurrently trained made greater gains in the number of repetitions performed at 80% of one-repetition maximum leg press compared to a group who had only resistance trained.

The inconsistent and conflicting results of the current research examining the effects of concurrent training present a problem for anyone who might engage in simultaneous resistance and endurance training. The problem is whether or not the benefits of these two types of training are mutually exclusive. Based on the current research a definitive answer cannot be given, and the results of different studies are difficult to compare due to vastly different methodologies. The methods found in the current literature differ in the modality of resistance training, the modality and duration of endurance training, timing of each training session within the concurrent training, the volume of training by each group, the training status of subjects prior to training, subject gender, and the types of performance and physiological testing. There is a clear need for more research investigating the interaction of resistance and endurance training using the types of training programs that are prescribed by organizations such as American College of Sports Medicine. Further research would allow the organizations and individuals around the world that prescribe exercise to better understand the consequences of prescribing endurance and resistance training simultaneously.

Thus, the purpose of this study was to examine whether or not endurance training and resistance training performed concurrently would produce different performance and physiological results when compared to resistance or endurance training alone. We tested the hypothesis that strength gains would be the same for the concurrent and resistance groups in the traditional test of maximum strength, but the resistance only group would make greater gains in the performance tests that required a rapid production of force (power). It was also hypothesized that the concurrent and endurance groups would make similar gains in endurance performance.

Methods

Subjects

Forty-five untrained men were recruited on a volunteer basis from the Texas A&M University population to serve as subjects for this study. Untrained was defined as not having participated regularly in either endurance or resistance training for at least three months. The acceptable age range was 18 – 40 years of age. The 45 subjects were randomly assigned to one of three groups (endurance training (ET, N=12), resistance training (RT, N=13), and concurrent training (CT, N=16)). Characteristics of subjects in the three groups are presented in Table 2. The final number of subjects in each group varies due to subject drop out and randomization. Four subjects failed to complete the study, three due to injury and one for unknown reasons. Subjects were informed of all possible risks involved in the study, and signed an informed consent previously approved by Texas A&M University's Institutional Review Board for Use of Human Subjects in Research. Subjects also completed a general health history questionnaire prior to the start of pre-testing. These questionnaires were reviewed to ensure each subject's safety in participating in the study.

TABLE 2. Subject characteristics by group.

Group	N	Age (yr)	Height (in)	Weight (lb)
ET	12	24.9 ± 4.8	69.9 ± 3.2	193.7 ± 36.7
RT	13	22.5 ± 3.3	68.7 ± 2.2	160.4 ± 26.2
CT	16	21.4 ± 2.2	71.6 ± 2.2	201.9 ± 37.8

Values are given as mean ± SD.

Pre-, Mid-, and Post-Training Testing

All subjects, regardless of group assignment, were tested before and after training for each of the following dependent variables; percent body fat, maximal oxygen consumption (VO_{2max}), isokinetic-maximal torque production and average power during knee extension and flexion at two different speeds, one repetition maximum (1RM) leg press, 1 RM barbell bench press, vertical jump, and 40 yard dash time (detailed procedures to follow). All pre- and post-training testing procedures were completed within a one-week period spaced 13 weeks apart. One day of rest and recovery was scheduled between each day of testing. VO_{2max} and percent body fat were measured on day one. All isokinetic testing was conducted on day two. Vertical jump, 40-yard dash time, and one-repetition maximums were measured on day three.

Mid-training testing was conducted during week seven of the study. All dependent variable measurements, except isokinetic measurements, were repeated during mid-testing. During this week testing was conducted on two days separated by at least 48 hours. Percent body fat and VO_{2max} measurements were completed on day one. 1 RM leg press, 1 RM bench press, vertical jump, and 40-yard dash time were all tested on day two.

Demographic Measurements, Body Composition, and Aerobic Capacity Measurements

Subject height and weight were measured to the nearest one half inch and one half pound, respectively. Body weight was monitored weekly during training. Body density was determined using the hydrostatic weighing technique. Percent body fat was estimated from body density by the formula developed by Brozek (10). Body volume was adjusted for residual lung volume estimated from the subject's age and height (17). Maximal oxygen consumption was determined by indirect, open-circuit calorimetry (MedGraphics® CPX/D) while the subject exercised to volitional fatigue on a motorized treadmill during a Bruce protocol (11). Two out of three of the following criteria were used to determine VO_{2max}: a plateau of oxygen consumption (defined as a rise of less than 2 ml/kg/min during final minute of test), a respiratory exchange ratio of greater than 1.15, and a heart rate within 10 beats of the age-predicted maximum (220-subject's age) (30). Resting and maximum-exercise heart rate measurements were taken during VO_{2max} testing through the use of Polar® heart rate monitors.

Isokinetic and Strength Measurements

Maximal torque production and average power were tested using a Biodex® isokinetic knee extension/flexion device at speeds of 60 and 180 degrees per second. Subjects performed a set of three and fifteen repetitions at the two speeds, respectively. The set of three at 60 deg/sec always preceded the faster set of 15. Peak torque and average power were recorded for both speeds, as well as for both flexion and extension. One-repetition maximums for leg press and bench press were determined by the maximum weight the subject could successfully lift one time with proper technique after completion of a standardized warm-up. The warm-up consisted of 5 minutes of cycling, 5 minutes of stretching, and 4 light sets of each exercise. During pre- and mid-training testing, the subjects in the RT and CT groups were required to perform a one repetition maximum test in all of the exercises that were incorporated into the resistance-training program. The exercises included leg press, leg curl, standing calf raise, barbell bench press, lat pull-down, dumbbell military press, and barbell curl.

Power and Speed Measurements

Vertical jump was tested using a jump and touch testing method with a Vertec vertical jump device (Sports Imports®, Columbus, OH). The standing reach of the subject's dominant hand was measured as the maximum height the subject could reach while standing flat-footed. Subjects were instructed to stand flat footed before jumping, and no step was allowed before the execution of the jump. Subjects were allowed three maximal jumps. Vertical jump height was determined by the difference between the subject's highest jump touch and the subject's standing reach. Lower-body power was then calculated using the Lewis formula: 2.21 * weight(kg) * √jump height(m)= ($kp*m*sec^{-1}$) (9). Forty-yard dash time was measured using an electrical timing device (Sportline®-model 220) and taking the fastest of three maximal attempts. Subjects were allowed to start in any position of their choice, and timing was initiated on first movement.

Training Program

The training varied for each of the three groups. Members of each group took part in a training program that lasted twelve weeks, allowing for one week of mid-training re-testing at week 7. The RT group trained by participating in a basic resistance-training program. Every odd numbered week this group trained two times per week, and every even numbered week this group trained three times per week. This training frequency was chosen so that the total number of resistance workouts would equal that of the CT group. The resistance-training program was a total body workout consisting of 3 sets of 6-10 repetitions on 8 exercises that trained all the major muscle groups, similar to the programs recommended by ACSM (2). The exercises included those previously listed (see isokinetic and strength measurements) and an abdominal crunch. A percentage of each subject's one-repetition maximum for each exercise was used to determine the intensity each week. The intensity and number of repetitions performed for each exercise changed bi-weekly. Mid-training testing allowed one-repetition maximums to be adjusted for weeks 8 – 13 of the resistance-training program. A more detailed description of the progression of the resistance-training program is presented in Table 3.

The ET group was trained by running on a treadmill or outdoors 2-3 times per week. This group followed the same pattern as the RT group by training twice on odd numbered weeks and three times on even numbered weeks. Thus, the total number of endurance workouts performed by the ET and CT groups were equal. The running intensity was determined by a percentage of heart rate reserve (HRR) through use of the Karvonen formula (24). Training sessions lasted between 20-40 minutes, and exercise heart rate was continuously monitored by Polar® heart rate monitors. Once again, this training program is similar to those prescribed by ACSM (2). The intensity and/or duration of each session were increased bi-weekly as training progressed. Resting and maximum heart rates were reassessed during mid-training testing in order to adjust the endurance training for weeks 8 – 13. A more detailed description of the progression of the endurance-training program is presented in Table 4.

The CT group trained five times per week. Every odd numbered week this group performed the RT program three times and the ET program twice. Every even numbered week the CT group performed the ET program three times and the RT program twice.

During training all subjects were asked to maintain their habitual diet. Compliance was evaluated through the use of three-day dietary records during the first and last weeks of training.

TABLE 3. Resistance training program progression.

Week #	1 & 2	3 & 4	5 & 6	8 & 9	10 & 11	12 & 13
Intensity	1 warm-up set of 10 reps @ 50% 1RM 3 sets 10 @ 75%	1 warm-up set of 10 reps @ 50% 1RM 3 sets 8 @ 80%	1 warm-up set of 10 reps @ 50% 1RM 3 sets 6 @ 85%	1 warm-up set of 10 reps @ 50% 1RM 3 sets 10 @ 75%	1 warm-up set of 10 reps @ 50% 1RM 3 sets 8 @ 80%	1 warm-up set of 10 reps @ 50% 1RM 3 sets 6 @ 85%

Mid-training testing conducted during week 7.

TABLE 4. Endurance training program progression.

Week #	1 & 2	3 & 4	5 & 6	8 & 9	10 & 11	12 & 13
Intensity	20 minutes @ 65% of HRR	25 minutes @ 70% of HRR	30 minutes @ 70% of HRR	35 minutes @ 75% of HRR	40 minutes @ 75% of HRR	40 minutes @ 80% of HRR

Mid-training testing conducted during week 7.

Data Analysis

A one-way analysis of variance with repeated measures was used to analyze pre-, mid-, and post-training values within each group for all dependent variables. Duncan's new multiple range test was employed for post hoc analyses of significant ANOVA results. The magnitude of changes for all dependent variables produced by training in the three groups (between group comparison) were compared using a one-way analysis of variance on the delta scores (calculated by subtracting pre-training values from post-training values for each variable) of each variable. Once again, Duncan's new multiple range test was employed for post hoc analyses of significant ANOVA results. $P \leq .05$

was considered significant. Ninety percent subject compliance (27 out of 30 workouts for the ST and ET groups and 54 out of 60 for CT group) was required for data to be included in the final statistical analysis. All subjects that completed the study met this compliance level.

Results

Demographic Measurements

The ET group showed no significant change in body weight after training, although there was a trend toward weight loss. In the RT group body weight was significantly elevated above pre-training levels at both the mid- (+1.96%) and post-training (+3.27%) time points. Mid- and post-training values were not significantly different. Body weight increased significantly from pre- to post-training (+1.53%) in the CT group. There was no change between pre- and mid-training or mid- and post-training for body weight in this group. Although not significant within the group, the change in body weight for the ET (-1.19%) group was significantly different when compared to the change in the RT (+3.27%) and CT (+1.53%) groups. No difference was found between the RT and CT groups' body weight changes (Fig. 1). Excluding isokinetic measurements, results for all dependent variables are presented in Tables 5 and 6.

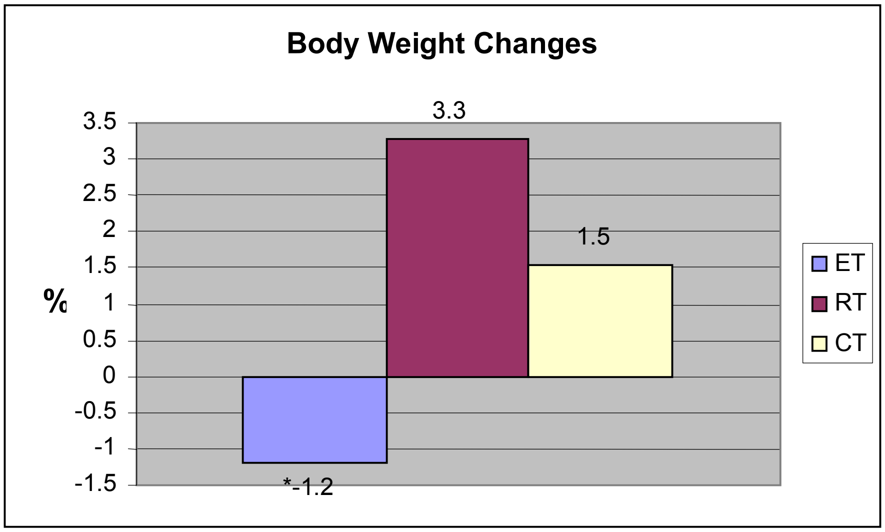

Figure 1-Percent body weight changes form pre- to post-training. * Significantly different from RT and CT changes. ($P \leq .05$)

TABLE 5. Demographic, body composition, and aerobic capacity results.

Variable	Group	Pre	Mid	Post
Body Weight (lb)	ET	193.7 ± 36.7	192.5 ± 34.7	191.4 ± 33.1
-	RT	160.4 ± 26.2	163.5* ± 25.4	165.7* ± 24.7
-	CT	201.9 ± 37.8	203.5 ± 34.6	205.0* ± 34.3
VO_{2max} (L/min)	ET	3.52 ± 0.67	3.74* ± 0.67	3.81* ± 0.60
-	RT	3.23 ± 0.47	3.23 ± 0.35	3.35 ± 0.36
-	CT	3.97 ± 0.61	4.03 ± 0.46	4.08 ± 0.48
% Body Fat	ET	20.5 ± 9.72	19.7 ± 8.77	19.1* ± 8.7
-	RT	15.9 ± 4.60	15.4 ± 4.98	15.3 ± 5.4
-	CT	18.3 ± 9.01	17.0* ± 8.88	17.0* ± 8.97

Values are given as mean ± SD.
* Significantly different from pre. ($P \leq .05$)

TABLE 6. Power, speed, and strength results.

Variable	Group	Pre	Mid	Post
Vertical Jump (in)	ET	18.75 ± 3.24	19.08 ± 2.99	19.33 ± 3.35
-	RT	20.50 ± 2.63	21.08 ± 3.09	21.38 ± 3.15
-	CT	20.34 ± 4.44	20.25 ± 4.8	20.41 ± 4.55
Power ($kp*m*sec^{-1}$)	ET	133.2 ± 23.3	133.9 ± 23.2	133.7 ± 20.9
-	RT	115.5 ± 18.7	119.5* ± 19.5	122.1*** ± 18.7
-	CT	143.2 ± 21.7	143.8 ± 19.7	145.5 ± 17.8
40-Yard Dash (sec)	ET	5.59 ± 0.43	5.71* ± 0.48	5.52** ± 0.38
-	RT	5.52 ± 0.29	5.56 ± 0.28	5.56 ± 0.30
	CT	5.58 ± 0.50	5.65 ± 0.53	5.59 ± 0.52
1 RM Leg Press (lb)	ET	595.0 ± 148.1	647.5* ± 157.8	716.7*** ± 182.0
-	RT	486.9 ± 101.7	585.0* ± 113.9	685.8*** ± 138.5
-	CT	611.9 ± 116.4	757.2* ± 166.8	852.8*** ± 165.9
1 RM Bench Press (lb)	ET	173.8 ± 48.7	173.3 ± 42.4	186.8*** ± 42.2
-	RT	146.2 ± 44.1	171.5* ± 42.7	190.8*** ± 41.0
-	CT	180.9 ± 43.8	205.0* ± 40.4	219.4*** ± 39.3

Values are given as mean ± SD
* Significantly different from pre. ** Significantly different from mid. *** Significantly different from pre and mid. ($P \leq .05$)

Body Composition and Aerobic Capacity Measurements

VO_{2max} was significantly increased above pre-training levels at both the mid- (+6.25%) and post-training (+8.24%) time points for the ET group. However, mid and post-training values were not significantly different. No change in VO_{2max} was found for the RT or CT groups. The magnitude of change in VO_{2max} within the ET group was not large enough to elicit any significant between-group differences. A significant decrease in percent body fat was found from pre- to post-training (-1.45%) in the ET group. No difference was found between pre- and mid-training values or between mid- and post-training values. No change in percent body fat was found in the RT group. Within the CT group percent body fat decreased significantly from pre- to mid-training (-1.25%) and from pre- to post-training (-1.25%). Mid- and post-training values were not significantly different. Between-group changes in percent body fat were not significant.

Isokinetic and Strength Measurements

Within the ET group the only significant change in any of the isokinetic measurements was a 5.32 % increase pre- to post-training in peak torque during extension at 180 deg/sec. Within the RT group average power during flexion at 60-deg/sec, as well as peak torque during flexion and extension at 180 deg/sec significantly increased from pre- to post-training (+10.1%, +10.4%, and +11.1%, respectively). No significant changes were found for any of the isokinetic measurements in the CT group. The only significant between-group difference for any of the isokinetic measurements was found in peak torque during flexion at 180 deg/sec. Here, the change in the RT (+11.1%) group was significantly greater than the changes in the ET (-1.27%) and CT (-5.26%) groups. No difference was found between the ET and CT groups in this measurement (Fig. 2).

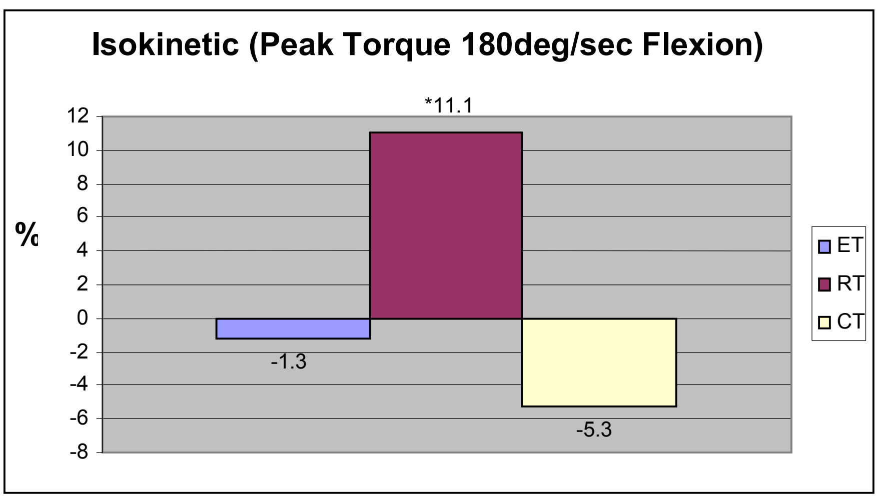

Figure 2-Percent changes in isokinetic peak torque during knee flexion at 180deg/sec from pre- to post-training. * Significantly different from ET and CT changes. ($P \leq .05$)

The ET, RT, and CT groups each significantly increased 1 RM leg press across all time points: pre- to mid-training (+8.82, +20.1, and +23.7 %, respectively), mid- to post-training (+10.7, +17.2, and +12.6%, respectively), and pre- to post-training (+20.4, +40.8, and +39.4%, respectively). The increases in 1 RM leg press from pre- to post-training for the RT and CT groups were significantly higher than that of the ET group. The leg press changes in the RT and CT groups were not different (Fig. 3). In the ET group 1 RM bench press showed no change from pre- to mid-training, but increased from mid- to post-training (+7.78%). Due to this increase the post-testing mean (+7.52%) was significantly higher than the pre-training mean. In the RT and CT groups 1 RM bench press significantly increased at all testing points: pre- to mid-training (+17.4 and +13.3%, respectively), mid- to post-training (+11.2 and +7.01%, respectively), and pre- to post-training (+30.5 and +21.2%, respectively). From pre- to post-training, the increase in 1 RM bench press was significantly higher in RT and CT groups compared to the ET group. There was no difference in bench press changes for the RT and CT groups (Fig. 4).

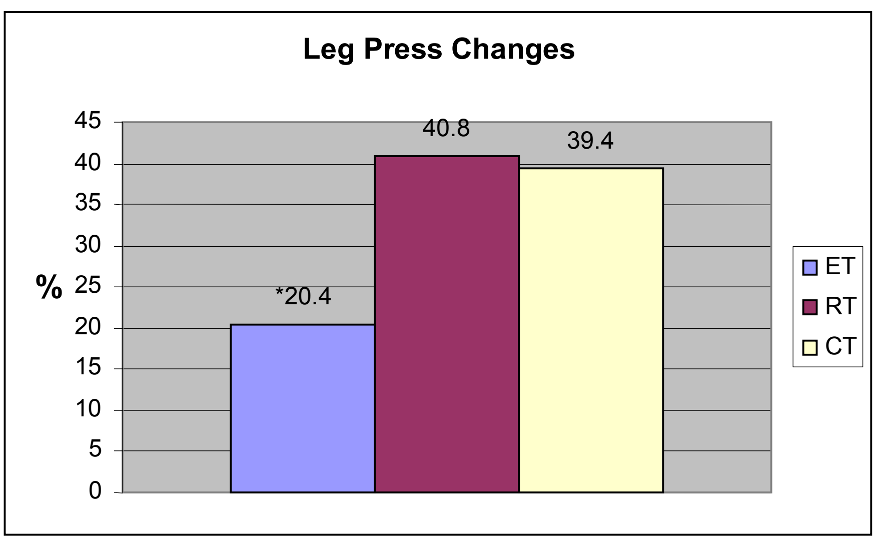

Figure 3-Percent changes in leg press from pre- to post-training. * Significantly different from RT and CT changes. ($P \leq .05$)

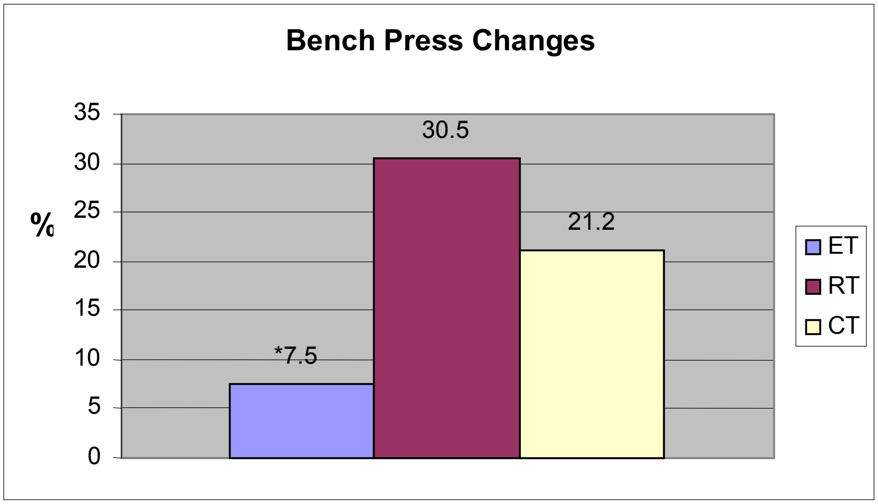

Figure 4-Percent changes in bench press from pre- to post-training. * Significantly different from RT and CT changes. ($P \leq .05$)

Power and Speed Measurements

No group showed any significant change in vertical jump. No significant differences exist between the changes or lack of changes that occurred for vertical jump in any of the three groups from pre- to post-training. Similar to vertical jump, no change in power was found within the ET or CT groups. Significant increases in power were found from pre- to mid-training (+3.46%), mid- to post-training (2.18%), and pre- to post-training (5.71%) in the RT group. Between-group comparisons revealed that the changes in power from pre- to post-training were not significantly different between the RT (5.71%) and CT (1.61%) groups, but the change that occurred in the RT group was significantly greater than the ET group (0.38%). No significant difference in power changes was found between the ET and CT groups (Fig. 5). In the ET group forty-yard dash time was significantly longer from pre- to mid-training (+2.15%). However, at the time of post-training forty-yard dash time (-3.44%) was found to be significantly shorter than at mid-training. Pre- and post-training values were not significantly different. The RT and CT groups showed no change in forty-yard dash time. Like vertical jump, no significant differences exist between the changes or lack of changes that occurred for forty-yard dash time in any of the three groups from pre- to post-training.

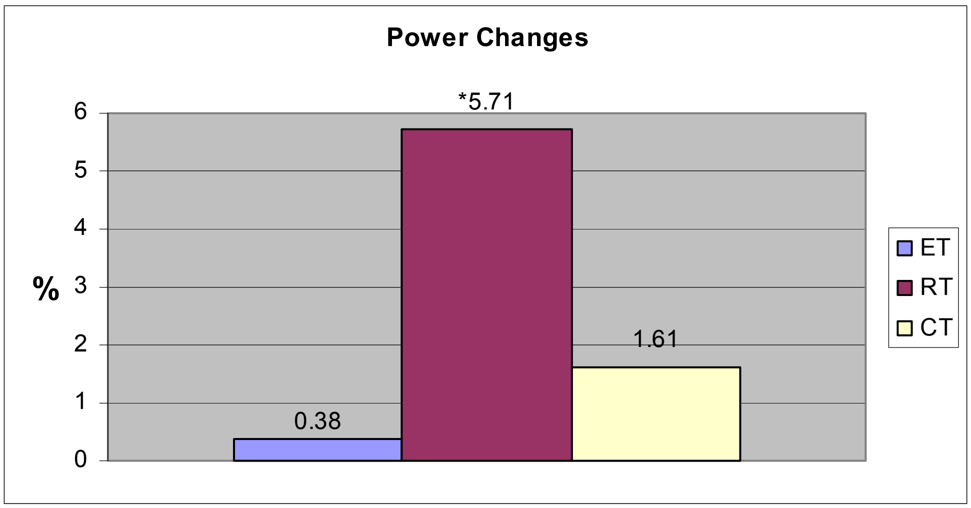

Figure 5-Percent changes in power from pre- to post-training. * Significantly different from ET changes. ($P \leq .05$)

Discussion

The goal of this investigation was to determine whether or not endurance training and resistance training performed concurrently would produce different performance and physiological results when compared to each type of training alone. Based on the existing research examining concurrent training and the design of our study we hypothesized that gains in maximum strength, but not power would be the same for the RT and CT groups. Moreover, we expected the maximum strength gains of the RT and CT groups to be greater than the ET group, and the power gains of the RT group to be greater than the CT and ET groups. We also hypothesized that the ET and CT groups would make similar improvements in VO_{2max}, but greater than the RT group.

In accordance with our hypothesis the RT and CT groups did make similar gains in maximum leg press and bench press strength. The gains seen by these two groups were significantly greater than the ET group gains. The improvements seen in 1 RM leg press by the RT (+40.8 %) and CT (+39.4 %) groups in our investigation are similar to or greater than those reported by earlier investigations that used either the same test or a very similar test, i.e. 1 RM squat (18,23,27,32). McCarthy et al. (27) reported no interference in strength gains and improvements in 1 RM squat of 23 and 22 percent for the resistance training and concurrent training groups, respectively. Factors such as initial fitness levels of the subjects, duration of training, training intensity, and the type of resistance and endurance training used could account for the larger gains seen in our investigation and the absence of interference. For example, Kraemer et al. (25) reported interference in the strength development of the concurrent training group, as well as leg press gains substantially lower than those found in our investigation. These findings might differ from ours due to the fact that the subjects in the Kraemer et al. investigation were physically active members of the US Army, and all groups were required to train four days per week. Other examples that varying methodologies may produce different results can be found in the literature. Hickson et al. (22), the first to report interference in strength development with concurrent training, required the resistance training group to train five days per week and the endurance training and concurrent training groups to train six days per week. Hennessy et al. (20), who also reported compromised strength gains with concurrent training, studied subjects that were competitive rugby players and had resistance training experience.

The specificity of training principle would not predict a significant increase in strength with endurance training, yet in our investigation we found a significant increase in 1 RM leg press by the subjects in the ET group. Although significantly less than the 1 RM leg press gains of the RT and CT groups, the ET group showed a substantial increase in leg strength (+20.4 %). These findings are in agreement with those of Wood et al. (36) showing that in untrained subjects endurance training alone caused a significant increase in leg extension (+24.1 %) and leg curl (+29.0 %) 5 RM. However, the average age (~ 68 yrs) of the subjects in the Wood et al. (36) study was much older than the age of the subjects in our investigation. Sale et al. (32) also reported that endurance training alone increased 1 RM leg press significantly (+20.3%). However, these results may have been due to the hybrid nature of the training program used in this study (endurance training = 3 minute bouts at 90=100% VO_{2max} and resistance training = sets of 15-20 repetitions). Another investigation, not involving concurrent training, but using endurance training intensities similar to ours reported significant increases in 1 RM leg press in untrained subjects after 12 weeks of endurance training (19).

Like 1 RM leg press, the increases in 1 RM bench press in the RT (+30.5 %) and CT (+21.2 %) groups are also similar to the magnitude of change reported by earlier investigators (20,23,25,27). Although the increase in 1 RM bench press within the RT group was greater than the increase in the CT group the difference was not statistically significant. Similar to 1 RM leg press, an increase in 1 RM bench press was seen within the ET group (+7.52 %). This increase in upper body strength seen with endurance training alone is highly unusual and difficult to explain, although such a finding is not without precedent in the literature. Wood et al.(36) reported an insignificant increase (+15.3%) in chest-press 5 RM in a group of older adults that only endurance trained, and Hass et al. (19) reported significant increases in 1 RM chest press and seated row after 12 weeks of endurance training using training intensities and durations similar to our investigation.

Also in accordance with our hypothesis a significant increase in lower-body power was only found in the RT group. This finding is in agreement with other investigations reporting significant increases in anaerobic power by the resistance training only groups (14,18,20,23,25,27). The increase in power by the RT group in our investigation was not large enough to make a significant between group difference when compared to the CT group; however, Kraemer et al. (25) reported power gains, as measured by the Wingate power test, by their resistance training group to be significantly greater than the concurrent training and endurance training groups. Due to the formula used to calculate power in our investigation, the increase in power within the RT group was largely due to a significant increase in body weight. To our knowledge no other investigation, examining the consequences of concurrent training, has used body weight and vertical jump to quantify lower body power. The only significant between group difference in our investigation was found between the power changes in the RT and ET groups. This finding is not unusual due to the fact that endurance training is not typically associated with an increase in anaerobic power.

Contrary to our hypothesis no significant change in vertical jump, often considered a representative of lower body power, was found within any of the three training groups. However, a trend toward an increase within the ET and RT groups did exist. Our findings are in disagreement with the previous literature showing that resistance training alone could cause significant increases in vertical jump (20,23,27). Two of these previous investigations reported that the group that performed concurrent training failed to improve vertical jump while the resistance training only group improved significantly (20,23). In contrast, McCarthy et al. (27) found similar improvements in vertical jump in concurrent and resistance trained groups. The results of our investigation showed that neither concurrent training nor strength training alone significantly improved vertical jump, and that endurance training alone had no affect on vertical jump. Other research has shown endurance training alone to cause decreases in vertical jump (26,34). Despite these various findings involving vertical jump, our results showed that vertical jump was unchanged by all training programs used in the present investigation.

In addition to vertical jump, no change in 40-yard sprint time was found within any of the three groups. This finding is in contrast with that of Hennessy et al. (20) who reported that a group that only resistance trained improved in 20-meter sprint time after 8 weeks of training, and the concurrent training and endurance training groups showed no change in this measurement. The lack of change in 40-yard sprint time found in our investigation is not unusual due to the nature of the training performed and the absence of any form of sprint training. Based on the specificity of training principle, some form of maximal or near maximal-velocity sprint type training would be required to significantly change 40-yard sprint time.

Minimal changes were found in any of the isokinetic measurements performed in our investigation. The RT group significantly increased in three of the eight isokinetic measurements made. However, the only significant between group difference was found in the measurement of peak torque during flexion at 180 deg/sec. In this measurement, the RT group increased significantly more than the ET and CT groups. This data somewhat supports our hypothesis that concurrent training would result in attenuated power gains. This finding is in agreement with the findings of Dudley and Djamil (14) showing that their concurrent and resistance training groups had similar improvements in maximum torque at low velocities (0 - 96.3 deg/sec), but the groups differed in their maximum torque production at higher velocities (96.3 - 240 deg/sec). It was speculated that changes in neural factors were responsible for the decreased ability of the concurrent group to rapidly produce force. However, McCarthy et al. (28) was recently the first to investigate changes in neural activation with concurrent training. The results of this study showed, through the use of EMG, that the amount of neural activation at a given torque was the same after concurrent and resistance training alone.

The absence of any other substantial isokinetic changes within or between groups in our investigation could be due to the fact that the resistance training program used was isotonic in nature, not isokinetic. Several other investigations that have used isokinetic resistance training programs have shown significant torque gains by the resistance and concurrent training groups (1,14,29). As previously stated, Dudley and Djamil reported that their concurrent and resistance training groups differed in their improvements at higher velocities. However, the two other studies that have used isokinetic training found similar improvements for the resistance and concurrent training groups at all testing velocities (1,29). The results of these investigations are difficult to compare to that of the present investigation due to different training protocols.

As stated previously, it was anticipated that in our investigation the ET and CT groups would make similar gains in VO_{2max}, and the gains seen by these two groups would be greater than any gain seen within the RT group. However, our data showed a significant increase in VO_{2max} within the ET group and no significant change within CT and RT groups. The increase in VO_{2max} within the ET group (+8.25%) in our investigation was less than that reported in other investigations. Percent increases of fifteen to twenty percent have been reported by other investigators (22,27). The smaller change found in our investigation could be partly due to the lower total volume of training performed by our subjects. Research has shown that when the total number of training sessions per week conducted over a 20 week period is increased from 1 to 3 to 5 there is a corresponding increase in the magnitude of gain in VO_{2max} (16,31). The majority of other investigations have required subjects to train three to six days per week. For example, Hickson et al. (22) trained their subjects six days per week for forty minutes per day and reported a twenty percent increase in VO_{2max}. In our study, the ET group was only required to train alternately two or three times per week for twenty to forty minutes. This large difference in total volume of training could account for the smaller magnitude of change found in our investigation. Using an endurance training program similar to ours, Hunter et al. (23) reported a 9.7 percent increase in VO_{2max} within their endurance training group. This increase is only slightly larger than that found in our investigation, and could be partly due to the fact that the subjects in the Hunter et al. (23) study trained four days per week.

The absence of any change in VO_{2max} within the CT group conflicts with the majority of existing literature examining concurrent training. Most studies have reported similar VO_{2max} improvements for the endurance and concurrent training groups (1,7,12,14,18,20,22,21,23,25,27,32). Only Nelson et al. (29) have shown concurrent training to inhibit aerobic adaptations. They reported an inhibition in aerobic development during the second half of their twenty week training program. The concurrent training group in their investigation showed a significant increase in VO_{2max} after the first ten weeks of training (+6.2%), but no change was found after the second ten weeks. The endurance training group in their study significantly increased VO_{2max} after ten weeks (+9%), as well as at the completion of the study (+16.8%). Here, the authors speculated that a dilution of mitochondrial volume caused by resistance-training-induced hypertrophy in the concurrent group might be responsible for these findings. It should also be noted that citrate synthase activity (an oxidative enzyme) only increased in the endurance training group as reported by Nelson et al. (29). We speculate that a dilution of mitochondrial volume could be an explanation for the absence of improvement in VO_{2max} in the CT group in our study. Unfortunately, we have no direct measure of muscle hypertrophy or oxidative enzyme levels to support our speculation.

Another possible explanation for the lack of improvement in VO_{2max} within the CT group is the fact that this group might have been in better physical condition to began the study. The average relative VO_{2max} within this group (44.0 ml/kg/min) was substantially higher than the ET (40.8 ml/kg/min) group to begin the study. This higher pre-training level of the CT group may have put this group closer to their genetic upper limit. It is also possible that with this greater beginning aerobic capacity, the endurance training program used in our investigation was not strenuous enough to elicit a significant improvement in VO_{2max} within this group. The mean pre-training VO_{2max} of CT group falls within the range considered average for young-active healthy males (44-50 ml/kg/min), where as the mean VO_{2max} for the ET group falls below this range (3).

As expected, no change in VO_{2max} was found within the RT group in this investigation. This finding is in agreement with numerous other investigations reporting no change in VO_{2max} within the resistance training groups, as well as research findings that resistance training has little effect on VO_{2max} (34). As previously stated, only the ET group showed a significant within group increase in VO_{2max}, however, the magnitude of this increase was not large enough to elicit any significant between group differences.

Within the ET group in our investigation, body weight did not change, yet a significant decrease in percent body fat was found from pre- to post-training. These findings are in agreement with other investigations that have used running as their mode of endurance training. Hunter et al. (23) reported no change in body weight in the endurance training group after twelve weeks of running four days per week. Hennessy et al. (20), using a running protocol four days per week, and Hickson et al.(22), using a running and cycling endurance training protocol, both reported significant decreases in percent body fat for their endurance training groups.

Unlike the ET group, the RT group in our investigation showed a significant increase in body weight. However, no change in percent body fat was found in this group. In agreement with our findings, both Hickson et al. (22) and Hennessy et al. (20) reported significant increases in body weight for their respective resistance training groups. Hickson et al. (22) also reported no change in percent body fat within their resistance training group. In our investigation the increase in body weight with no change in percent body fat is likely explained by an increase in lean body mass within the

RT group from pre- to post training (135.0 to 140.4 lb). An increase in lean body mass is a well known adaptation to resistance training (3,9,22).

The CT group, similar to the RT group, showed a significant increase in body weight. This finding is in disagreement with current literature reporting concurrent training to result in either no change in body weight or a slight decrease (20,22,23,27). Due to the fact that the CT group in this investigation showed a significant decrease in percent body fat, the increase in body weight in this group is likely the result of an increase in lean body mass from pre- to post-training (165 to 170.2 lb). The finding of this investigation that concurrent training resulted in a significant decrease in percent body fat is in accordance with several other studies (20,22,23,27). Once again, this is most likely due to an overall increase in lean body mass caused by resistance training.

In conclusion, the findings of this investigation do not support the idea of an "interference phenomenon" associated with concurrent training and strength gains. Despite the findings of numerous other investigations reporting an interference of strength development with concurrent training, the data from this investigation, in accordance with our hypothesis, showed strength gains to be similar for the concurrent and resistance training groups. Also in accordance with our hypothesis, only the RT group in this investigation showed a significant change in lower body power, as calculated by the Lewis formula (9). In disagreement with our hypothesis very minimal changes were found for vertical jump and any of the isokinetic measurements that were made. Also in disagreement with our hypothesis, the data gathered in this investigation suggest interference in aerobic development with concurrent training. Based on the findings of this investigation the following recommendations can be made: For the average person training for health benefits, performing concurrent training is probably the best way to improve their physical fitness from a cardiovascular and muscular standpoint. For those individuals interested in maximizing there aerobic development, resistance training should be kept to a minimum. Lastly, although not studied in this investigation, athletes would be best advised to follow the principle of specificity, which means performing training that is specific to the types of movements and energy systems used in their respective sports.

CHAPTER III

CONCLUSIONS

This investigation has shown that in the present subject population of untrained, healthy males, age 18-40, concurrent resistance and endurance training does not interfere with strength gains when compared to resistance training alone. This investigation has also shown that significant strength improvements can be made from endurance training alone in an untrained male subject population. It can also be concluded that the endurance and resistance training programs used in this study will not elicit any change in speed or vertical jump. This lack of change in 40-yard sprint time found in this investigation is not unusual due to the nature of the training performed and the absence of any form of sprint training. The results of this investigation showed that neither concurrent training nor strength training alone improved vertical jump, and that endurance training alone had no affect on vertical jump. The principle of training specificity would not predict any significant change in vertical jump without the inclusion of some type specific jump training. However, the data collected in this investigation did show that the resistance training program used in this study could elicit significant increases in power, as calculated by the Lewis formula (9).

In addition, the data from this investigation showed that the training programs used elicited minimal to no change in any of the isokinetic measurements made. The absence of substantial isokinetic changes in this investigation could be due to the fact that the resistance training program used was isotonic in nature, not isokinetic. Another conclusion that can be drawn from the results of this investigation is that resistance training interferes with the aerobic adaptations associated with endurance training.

Interference in aerobic development in this study could have been due to a resistance training induced reduction in mitochondrial volume, a higher than average beginning fitness level in the subjects of the concurrent group, too low of a volume of endurance training in this group, or to low of intensity of training in this group. A definitive answer cannot be made from the data acquired during this investigation.

Moreover, it can be concluded from the results of the present investigation that percent body fat is decreased and body weight is unchanged by the endurance training program used in this study. Unlike the endurance training program, the resistance training program in this investigation caused a significant increase in body weight and no change in percent body fat. When the two programs were performed together, concurrent training, the combined effect was a significant increase in body weight and a reduction in percent body fat. It should be noted that the results of the present investigation and any conclusions made based on those results are only applicable to the subject population used in this study.

Much more research is needed before any definite statements can be made regarding the effects that resistance and endurance training have on each other. Due to the vastly different methodology within the current research it is difficult to compare results across studies. The significant findings of this investigation are that similar strength gains can be made with either concurrent training or resistance training alone, and that resistance training hinders aerobic development. Based on these findings the following recommendations can be made: For the average person training for health benefits, performing concurrent training is probably the best way to improve their physical fitness from a cardiovascular and muscular standpoint. For those individuals interested in maximizing there aerobic development, resistance training should be kept to a minimum. Lastly, although not studied in this investigation, athletes would be best advised to follow the principle of specificity, which means performing training that is specific to the types of movements and energy systems used in their respective sports.

Recommendations

The following recommendations for future research are based on the results of this investigation and the related literature.

1. It is recommended that further research be designed to investigate the effects of concurrent training based on gender.
2. It is recommended that further research be designed to investigate the effects of concurrent training in an older subject population.
3. It is recommended that further research be designed to investigate the effects of concurrent training on both previously endurance and resistance trained subjects.
4. It is recommended that further research be conducted using more strenuous training programs.
5. It is recommended that future study include analysis of skeletal muscle morphology, skeletal muscle capillarization, muscle metabolic enzymes, hormone concentrations, as well as all the dependent variables measured in this investigation.

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APPENDIX A

INFORMED CONSENT

Informed Consent

Title of the Study: The Effects of Concurrent Training on Performance Variables in Previously Untrained Males

Investigator: **Office Phone:**

Shawn P. Glowacki, B.S. (979) 845-9418

Address of Shawn P. Glowacki, Principal Investigator:

503 Southwest Parkway #1207

College Station, TX 77840

I,____, have been informed by the investigators that I have been selected to participate in a study entitled: *The Effects of Concurrent Training on Performance Variables in Previously Untrained Males.*

I understand this study will be conducted between February 1, 2003 and May 1, 2003 at the Applied Exercise Science Laboratory located in the Steed building at Texas A&M University, College Station, Texas. Thirty males from Texas A&M University will be recruited for this study. To be considered as a subject for this study, I must: 1) be a male between the ages of 18 and 40 years; 2) **not** be regularly participating in any endurance or resistance type exercise for at least the last three months 3) be generally healthy without any known medical or physical problems which would keep me from performing endurance or resistive exercise; and 4) **not** use tobacco products and excessive consumption of alcohol (> 2 oz. per day).

GENERAL INFORMATION CONCERNING MY RIGHTS AS A STUDY PARTICIPANT

I have been invited to participate in a research study about the effects of concurrent training on performance variables in previously untrained men. Concurrent training is defined for this study as strength and endurance training combined. I have been informed that persons who participate in research are entitled to certain rights. These rights include but are not limited to my right to:

1. Be informed of the nature and goal of the research.

The general goal of this research project is to determine whether concurrent training interferes with the strength/power gains that are seen with strength training alone.

To fulfill this general goal, this project has been designed to answer the following question.

> Does participating in endurance and strength training simultaneously, concurrent training, attenuate the strength/power gains that are seen when one participates in only strength training?

Procedures to be Followed:

After I volunteer and give my informed consent to be a subject in this study, I understand I will be given a health history questionnaire to answer. I will be encouraged to answer these questionnaires to the best of my knowledge so that the investigators can make an accurate decision about the safety of the study for me. Following review of the questionnaire, the investigators will make a decision about allowing me to continue in the study. If I am selected to continue, I will be randomly assigned to one of three exercise groups (endurance-only, strength-only, and concurrent). After being randomly place in one of the three groups I will ask to take part in the pre-training testing one week prior to the start of the training program.

As a subject, regardless of group assignment, I understand I will be tested in all the following variables one week prior to training: percent body fat, maximal oxygen consumption (VO_2 max), maximal torque production at two different speeds, one repetition maximum leg press, one repetition maximum bench press, vertical jump, and 40 yard dash time. As a subject I will also read as well as be verbally explained the methods and procedures that will be used to determine each of the above variables. Percent body fat will be determined through the use of hydrostatic weighing. Maximal oxygen consumption will be determined by the subject exercising to volitional fatigue on a motorized treadmill. The peak oxygen uptake achieved during exercise will be recorded as VO_{2max} (L/min). Maximal torque production will be tested using a Biodex isokinetic knee extension device at speeds of 90 and 240 degrees per second. Here the subjects will exert a maximal force at a velocity of 90 and 240 degrees per second while maximal torque and power are recorded.

One-repetition maximums for leg press and bench press will be determined by the maximum weight the subject can successfully lift one time with proper technique after completion of a standardized warm-up. Subjects in the strength and concurrent groups will be required to perform a one repetition maximum test in all of the exercises that will be incorporated into the strength-training program. Vertical jump will be determined by the difference in the subjects' standing reach and the highest touch during a maximal jump test. Forty-yard dash time will be measured using an electrical timing device and taking the fastest of three maximal attempts. Body weight will also be measured to the nearest one-half pound prior to training as well as weekly during training.

As a subject I understand that upon completion of the pre-training testing described above I will begin the training program. I am aware that training will vary depending on which group I am placed in. I understand that each group will take part in a training program that will last twelve weeks, allowing for one week of mid-training re-testing. The strength-training group will train by participating in a basic resistance-training program. Every odd number week this group will train two times per week, and every even number week this group will train three times per week. The resistance-training program will be a total body workout consisting of 2-4 sets of 6-12 repetitions on 8 exercises that train all the major muscle groups. The exercises will include leg press, leg curl, standing calf raise, barbell bench press, lat pull-down, dumbbell military press, barbell curl, and an abdominal crunch. A percentage of each subject's one-repetition maximums will be used to determine the intensity the subjects will work at each week. The intensity and number of repetitions performed for each exercise will change bi-weekly. The endurance only group will train by running on a treadmill 2-3 times per week. This group will follow the same pattern of the strength-training group by training twice on odd number weeks and three times on even number weeks. The running intensity will be determined by a percentage of the subject's maximum heart rate. Sessions will last between 20-40 minutes. The intensity and duration of each session will increase bi-weekly as training progresses. The concurrent training group will train five times per week. Every odd number week this group will perform the strength program three times and the endurance program twice. Every even number week the concurrent group will perform the endurance program three times and the strength program twice.

I understand that percent body fat, VO_2 max, one repetition maximum leg press, one repetition maximum bench press, vertical jump, and 40 yard dash time will all be re-tested during week seven of the study. I am aware that all testing will be conducted using the same methods and procedures that were used during the pre-testing. It has been explained to me that this re-testing will allow one-repetition maximums to be adjusted for weeks 8 – 13 of the strength-training program. The week following completion of the training program I understand that all the variables tested during pre-testing will be tested for the final time, and that this post-training testing will follow the same methods and procedures as the pre-training testing.

<u>Discomforts or Risks to be Reasonably Expected:</u>

I understand that the following few paragraphs give me information about the potential risks and discomforts that I may experience as a result of participating in this study. Additionally, the investigators have invited me to voice questions and concerns at any time during the course of the study so they may address these as they arise.

I understand that the risks associated with the one repetition maximum test and the graded exercise treadmill test (VO_{2max}) are comparable to those I face whenever I perform hard exercise that causes me to sweat and breathe heavily. These include the risk of occasional abnormal blood pressure responses, injury to joints or muscles, such as ankle, knee, or hip sprains or, rarely, fractures, muscle strains/soreness, syncope, heart dysrhythmia, severe dyspnea, and, in rare instances, heart attack. I have been informed that studies have shown my risk for death during this type of test is about 0.5 in 10,000, and my risk for harmful affects is about 5 to 8 in 10,000. The investigators have assured me that they will make every effort to minimize these risks by carefully reviewing my health and medical history questionnaire and evaluating my risk factors for disease. All these procedures will be done before I am allowed to exercise. If they find some physical problems that, in their judgment, make exercise risky, for my own protection they will not allow me to exercise in this study. In addition to the pretest procedures, trained exercise technicians and exercise physiologists will be in charge of conducting the test. They are trained to recognize problems in my heart or in other bodily responses to the exercise test which could be dangerous, and to stop the test if necessary. Throughout all testing procedures, the 6th edition of the American College of Sports Medicine's "Guidelines for Exercise Testing and Prescription" will be closely observed.

I also understand that the risks associated with the resistance or endurance-training sessions are comparable to those I face whenever I perform hard exercise that causes me to sweat and breathe heavily. These include the risk of occasional abnormal blood pressure responses, injury to joints or muscles, such as ankle, knee, or hip sprains or, rarely, fractures, muscle strains/soreness, syncope, heart dysrhythmia, severe dyspnea, and, in rare instances, heart attack. The investigators have assured me that they will make every effort to minimize these risks by carefully reviewing my health and medical history questionnaire and evaluating my risk factors for disease. All these procedures will be done before I am allowed to exercise. If they find some physical problems that, in their judgment, make exercise risky, for my own protection they will not allow me to exercise in this study. In addition, trained exercise technicians and exercise physiologists will be in charge of conducting the exercise training sessions and observing my heart rate and blood pressure during exercise. They are trained to recognize problems in my heart or in other bodily responses to the exercise test that could be dangerous, and to stop the exercise session if necessary. Throughout all exercise-training sessions, the 6th edition of the American College of Sports Medicine's "Guidelines for Exercise Testing and Prescription" will be closely observed.

The vertical jump test requires that I jump to my maximal ability. I understand that there is a possibility that I may injury myself upon landing but that this risk is minimal. This test will be administered on a level Astroturf surface to decrease the risk of injury.

The 40-yard dash test requires that I run as fast as I can for 40 yards in a straight line on Astroturf surface. I understand that during such a test, it is possible to suffer a muscle injury. This risk is minimal.

The body composition test requires that I be seated on a chair attached to scale in a tank of warm, shallow water (4 ft.). I will be asked to exhale all the air in my lungs and submerge myself completely. This procedure, though somewhat uncomfortable, is completed under the supervision of a trained technician and presents no more risks than swimming in an open pool under the supervision of a lifeguard.

Benefits of participation and alternative procedures:

I understand that the pre-training screening will provide valuable information to me regarding my present physical fitness status. Furthermore, blood pressure and heart rate will be monitored during the VO_{2max} test; this will provide me with important information related to the functional status of the cardiovascular system during maximal exertion. The muscular strength, power, and speed tests will provide me valuable information as well. These tests are often used to determine athletic status. From these tests, I can determine my strengths and weaknesses relative to my optimal physical conditioning. The body composition assessment will provide me with information regarding my ideal body weight and, if applicable, suggest the amount of fat that may be reasonably and safely lost or suggest the amount of weight that should be safely gained. The training program that I will be participating in will provide twelve weeks of supervised training by an experienced exercises physiologist. This training will allow me the opportunity to improve my current physical fitness status.

Compensation:

As a subject in this study, I understand I will receive the previously outlined evaluations, tests, and training at no cost to me. I will be given my individual results for; all screening procedures, the muscular strength test, the power test, the speed test, the maximal oxygen consumption test (VO_{2max}), and the percent body fat test. These results will be made available to me upon completion of all data analysis.

The investigators have informed me that they will make reasonable and proper efforts to prevent physical injury to me and to insure my safety throughout all phases of this research project. However, I am well aware that, as noted above, my participation in this study is not without risk. I understand that compensation for physical injuries or adverse effects incurred as a result of participating in this research is NOT available. **In the event of any emergency the investigators will call 911, however, Texas A&M University or the principle investigator will not cover any resulting medical bills or expenses.** The investigators have informed me that they are prepared to advise me about medical treatment in case I experience adverse consequences of any of the study procedures. However, I understand that it is my responsibility to report any injuries or ill effects to one of the investigators or study supervisors as soon as possible. The investigators have also provided me with Student Health Services Dial A Nurse number (979-845-2822) and the Health Center number (979-845-1511). I can access this system in case I have additional questions about my medical treatment. Phone numbers where the investigators may be reached are listed in the heading of this form.

Questions concerning the research and the procedures involved:

I understand that should I volunteer for this study; the procedures will be discussed with me in detail by one of the investigators. If I have any questions about the research or about my rights as a subject, the investigators have invited me to ask them. I am aware that if I have any questions later, I am invited to contact one of the investigators listed in the heading of this form.

Be instructed that consent to participate in the research may be withdrawn at any time, and that I may discontinue participation without prejudice.

Participation in this research is entirely voluntary. Refusal to participate will involve no penalty of any kind. If I decide to participate, I am free to withdraw my consent and discontinue participation at any time and for any reason. This will be without prejudice and any results, which were obtained up to the time of my withdrawal, will still be reported to me.

Be informed of the conditions under which my participation may be terminated by the investigator without regard to my consent.

I understand that falsification of any information provided by me to the investigators, whether verbal or written, will be grounds for termination of my participation without my consent. Furthermore, failure to comply with schedule of the training program may result in termination of my participation in this study without my consent.

I have the opportunity to decide to consent or not to consent to participate in research without the intervention of any element of force, fraud, deceit, duress, coercion, or undue influence on my decision.

My right to privacy.

I understand that I have the right to privacy. All information that is obtained in this study that can be identified with me will remain confidential, and will be stored in the laboratory of the principal investigator. All information that can be identified with me will be known only to the investigators and to those who will be responsible for statistical analysis of the data. It may be released to another physician of my choice upon my written request. The results of this study may be published in scientific journals without identifying me by name. I have been given and have read an explanation of the procedures to be followed in this study, including an identification of those, which are experimental. I have been given and have read a description of the attendant risks and discomforts that may be associated with the experimental procedures used in this study. I have been given and have read a description of the benefits that I may expect from participating in this study. I have been offered an answer to any inquiries concerning the procedures. I have been assured that steps will be taken to insure the confidentiality of my results, which will be housed in the Applied Exercise Science Laboratory. Neither my name nor any other descriptor that can identify me will be associated with the publication of the results of this study.

I understand that in the event of physical injury resulting from the research procedures described to me, there will be no financial compensation or free medical treatment offered to me.

I have not been requested to waive or release the institution, its agents or sponsors from liability for the negligence of its agents or employees. I have read and understand the explanations provided to me and voluntarily agree to participate in this study.

I understand that I will be given a copy of the entire informed consent document to keep for my own records.

Date_____________ Signature of Subject: __________________________

Address: ___________________________

____

Signature of Principal Investigator: _________________

This research has been reviewed and approved by the Institutional Review Board - Human Subjects in Research, Texas A&M University. For research related problems or questions regarding subjects' rights, the Institutional Review Board may be contacted through Dr. Michael W. Buckley, Director of Research Compliance, Office of the Vice President for Research at, (979) 845-8585 (mwbuckley@tamu.edu).

I understand that, in case of any further questions, I may contact one of the following individuals:

Shawn P. Glowacki, B.S. (Graduate Researcher)

503 SW Parkway #1207

(979) 845-9418

Stephen F. Crouse, Ph.D. (Advisor)

Applied Exercise Science Laboratory

(979) 845-3997

APPENDIX B

HEALTH HISTORY QUESTIONNAIRE

Texas A&M University

Health and Lifestyle Profile Questionnaire

Participant Information

Name____ **Social Security Number**____
____

Address____
____

City_______________________________ **State**__________ **Zip Code**__________
____

Home Telephone________________________ Work Telephone___________
____

Date of Birth___________________________ **Age**______ **Gender**: ❑ Male
❑ Female

Primary Physician_____________________________ Phone Number______
____

Biometrics

Body Frame Size: ❑ Small ❑ Medium ❑ Large

What is your percent body fat? (leave blank if you don't know) ___________%

If you do not know the percentage, check the box that describes your body fat %.
❑ High ❑ Normal or Low ❑ Don't Know

What is your blood pressure (mm Hg)? __________/__________

If you do not know the numbers, check the box that describes your blood pressure.
❑ High ❑ Normal or Low ❑ Don't Know

What is your blood cholesterol (mg/dl)?________

If you do not know the number, check the box that describes your blood cholesterol.

❑ High ❑ Normal or Low ❑ Don't Know

What is your HDL (mg/dl)?_______

If you do not know the number, check the box that describes your HDL.

❑ Low ❑ Normal or High ❑ Don't Know

What is your LDL (mg/dl)?_______

What is your triglycerides level (mg/dl)?________

What is your blood glucose level (mg/dl)?_______

Tobacco

Cigarette Smoking

How would you describe your cigarette smoking habits?

- ❑ Never Smoked (go to next section)
- ❑ Used to Smoke (go to B)
- ❑ Still Smoke (go to A)

A. Still Smoke

How many cigarettes a day do you smoke?____________

B. Used to Smoke

How many years has it been since you smoked cigarettes fairly regularly? __

What was the average number of cigarettes per day that you smoked in the 2 years before you quit?__________

Cigars and pipes

How many cigars do you currently smoke per day?__________

How many pipes of tobacco do you currently smoke per day?________

How many times per day do you currently use smokeless tobacco? __________

Safety

In the next 12 months how many thousands of miles will you travel by each of the following?

______,000 Car, truck, van:

______,000 Motorcycle:

On a typical day how do you usually travel?

- ❑ Walk
- ❑ Bicycle
- ❑ Motorcycle
- ❑ Sub-compact or compact car
- ❑ Mid-size or full-size car
- ❑ Truck or van
- ❑ Bus, subway, or train

- ❑ Mostly stay at home

What percent of the time do you usually buckle your safety belt when driving or riding?______

On average, how close to the speed limit do you usually drive?

- ❑ Within 5 mph of limit
- ❑ 6-10 mph over limit
- ❑ 11-15 mph over limit
- ❑ More than 15 mph over limit

How many times in the last month did you drive or ride when the driver had perhaps too much alcohol to drink?____________

Do you have working smoke detectors in your home?

❑ Yes ❑ No

Do you have a working fire extinguisher in your home?

❑ Yes ❑ No

Does every bathtub and bathroom floor in your home have a nonskid surface or rubber mat?

❑ Yes ❑ No

When you lift a heavy object do you bend your knees and keep your back straight?

❑ Yes ❑ No

Nutrition

How many drinks of alcoholic beverages do you have in a typical week?

______Beers

______Wine

______Wine Coolers

______Liquor

How many DAILY servings of the following do you usually eat?

Servings	Food	Serving Size
	Breads, cereal, rice and pasta	1/2 cup
	Vegetables	1/2 cup
	Fruit	1/2 cup
	Milk, yogurt, and cheese	1 cup
	Meat, poultry, dry beans, eggs and	Size of a deck of cards

	nuts	

How often do you eat foods high in fat such as fatty meat and fried foods?

- ❑ Daily
- ❑ 3-6 times per week
- ❑ 1-2 times per week
- ❑ A few times per month
- ❑ Rarely

How many 8 oz glasses of water do you usually drink each day (include all fluids not containing caffeine or
alcohol / i.e. juice, caffeine free tea, milk, etc.)?________

Stress

How do you feel you are currently coping with life in general?

- ❑ Seldom stressed, coping very well
- ❑ Sometimes stressed, coping fairly well
- ❑ Often stressed, trouble coping at times
- ❑ Heavily stressed, often have trouble coping
- ❑ Excessively stressed, unable to cope

Have you felt tired, worn out, used up or exhausted during the past month?

- ❑ The majority of the time
- ❑ Less than half of the time
- ❑ Only occasionally
- ❑ Seldom or never

How supportive do you feel your family and close friends are?

- ❑ Very supportive
- ❑ Somewhat supportive
- ❑ Not very supportive

Check all of the following stress management techniques that you use:

- ❑ Participate in a hobby
- ❑ Belong to a social group
- ❑ Practice deep relaxation 3x/wk
- ❑ Practice time management skills

Exercise

How often do you do strength building exercises such as situps, pushups or use weight training equipment?

- ❑ Seldom or never
- ❑ Once a week
- ❑ Twice a week
- ❑ Three or more times per week

How often do you do stretching exercises specifically for your lower back and thighs?

- ❑ Seldom or never
- ❑ Once a week
- ❑ Twice a week
- ❑ Three or more times per week

Which selection best describes your general ACTIVITY LEVEL for the PREVIOUS MONTH?

"Moderate Activities" include brisk walking, heavy housework, yard work, and recreational sports.
"Heavy Activities" include running, aerobic dance, heavy moving and competitive sports like basketball, soccer, etc.

Pick only one!

- ❑ Avoid all exercise and physical activity

- ❑ Walk for pleasure, routinely use stairs, etc.
- ❑ Some moderate activity (10 to 60 minutes per week)
- ❑ More moderate activity (over one hour per week)
- ❑ Some heavy activity (less than 30 min/week)
- ❑ Heavy activities totaling 30-60 min/week
- ❑ Heavy activities totaling 1-3 hours/week
- ❑ Heavy activities totaling 3+ hours/week

Women Only (men skip to Preventive Exams)

At what age did you have your first menstrual period? _____ years

How old were you when your first child was born (if no children, leave blank)?- ____years

How many women in your natural family (mother and sisters only) have had breast cancer? _____

Have you had a hysterectomy?
❑ Yes ❑ No

Preventive Exams

		Last	Exam			
Preventive Exams	Never	**<30 days**	**<1 Year**	**< 2 Years**	**<3 Years**	**<5 years**
Physical Exam	❑	❑	❑	❑	❑	❑
Dental Exam	❑	❑	❑	❑	❑	❑
Digital Rectal Exam	❑	❑	❑	❑	❑	❑
Stool Blood Test	❑	❑	❑	❑	❑	❑
Sigmoidoscopy	❑	❑	❑	❑	❑	❑
Self Skin Exam	❑	❑	❑	❑	❑	❑
Women						
Self Breast Exam	❑	❑	❑	❑	❑	❑
Clinical Breast Exam	❑	❑	❑	❑	❑	❑
Mammography	❑	❑	❑	❑	❑	❑
Pap Smear	❑	❑	❑	❑	❑	❑
Men						
Self Testicular Exam	❑	❑	❑	❑	❑	❑
Prostate-Specific Antigen	❑	❑	❑	❑	❑	❑

Medical History

Have you ever been told that you have diabetes?
❑ Yes ❑ No

Have you ever had cancer?
❑ Yes ❑ No

Has a doctor ever told you that you have heart disease?
❑ Yes ❑ No

Do you have fair skin?
❑ Yes ❑ No

Do you use sun block?
❑ Yes ❑ No

Check below the medical conditions experienced by someone in your immediate family (parents, grand parents, brothers, or sisters).
❑ Heart attack ❑ Diabetes
❑ Stroke ❑ High blood pressure
❑ Cancer ❑ Alcoholism

Do you have any orthopedic problems that limit your ability to exercise?
❑ Yes ❑ No If yes, Explain ________________________
____

How would you rate your overall health on a scale of 1 – 10 (1 = poor , 10 = Excellent)? ______

How would you rate your risk of heart disease on a scale of 1 to 10 (1 = high, 5 = average, 10 = low)? ______

How would you rate your body composition (percent fat) on a scale of 1 to 10 (1=very overweight ,
5 = average, 10 = very lean)? ______

How many days in the last year have you been sick enough to miss work? ______

Additional Questions

Please list any medications you are currently taking:

____
______

Please list any other physical conditions or medical ailments that you may have that were not addressed in this questionnaire:

APPENDIX C

SAMPLE WORKOUTS

Endurance Week # 1 Workout

Name:	______________	Resting HR:	60	Max HR:	195	Weight: ______

Session # 1 Date: ______________

Workout Time:	20 min	Treadmill Speed:	______	Workout RPE:	______
Target HR Range:	141 - 155	Treadmill Grade:	______		
EX HR:	______				

Session # 2 Date: ______________

Workout Time:	20 min	Treadmill Speed:	______	Workout RPE:	______
Target HR Range:	141 - 155	Treadmill Grade:	______		
EX HR:	______				

Endurance Week # 2 Workout

Name: ______________ Resting HR: 60 Max HR: 195 Weight: ______

Session # 1 Date: ______________

Workout Time: 20 min Treadmill Speed: ______ Workout RPE: ______

Target HR Range: 141 - 155 Treadmill Grade: ______

EX HR: ______

Session # 2 Date: ______________

Workout Time: 20 min Treadmill Speed: ______ Workout RPE: ______

Target HR Range: 141 - 155 Treadmill Grade: ______

EX HR: ______

Session # 3 Date: ______________

Workout Time: 20 min Treadmill Speed: ______ Workout RPE: ______

Target HR Range: 141 - 155 Treadmill Grade: ______

EX HR: ______

Strength Week # 1 Workout

		Leg Press		Leg Curl	Calf		Bench	Lat. PD		DB. Military	Curl	
Name: ______												
Weight: ____		*400*		*100*	*100*		*100*	*100*		*100*	*100*	
Session # 1	Date: ______											
		Set # 1			Set # 2			Set # 3			Set # 4	
	Leg Press	200	x 10		300	x 10		300	x 10		300	x 10
	Leg Curl	50	x 10		75	x 10		75	x 10		75	x 10
	Calf Raise	50	x 10		75	x 10		75	x 10		75	x 10
	Bench Press	50	x 10		75	x 10		75	x 10		75	x 10
	Lat. Pull Down	50	x 10		75	x 10		75	x 10		75	x 10
	DB. Military	50	x 10		75	x 10		75	x 10		75	x 10
	Barbell Curl	50	x 10		75	x 10		75	x 10		75	x 10
	Abs:											

		Leg Press		Leg Curl	Calf		Bench	Lat. PD		DB. Military	Curl	
		400		*100*	*100*		*100*	*100*		*100*	*100*	
Session # 2	Date: ______											
		Set # 1			Set # 2			Set # 3			Set # 4	
	Leg Press	200	x 10		300	x 10		300	x 10		300	x 10
	Leg Curl	50	x 10		75	x 10		75	x 10		75	x 10
	Calf Raise	50	x 10		75	x 10		75	x 10		75	x 10
	Bench Press	50	x 10		75	x 10		75	x 10		75	x 10
	Lat. Pull Down	50	x 10		75	x 10		75	x 10		75	x 10
	DB. Military	50	x 10		75	x 10		75	x 10		75	x 10
	Barbell Curl	50	x 10		75	x 10		75	x 10		75	x 10
	Abs:											

Strength Week # 2 Workout

Name: ____________________

Weight: ______

Leg Press	Leg Curl	Calf	Bench	Lat. PD	DB. Military	Curl
400	*100*	*100*	*100*	*100*	*100*	*100*

Session # 1 Date: ______________

	Set # 1		Set # 2		Set # 3		Set # 4	
Leg Press	200	x 10	300	x 10	300	x 10	300	x 10
Leg Curl	50	x 10	75	x 10	75	x 10	75	x 10
Calf Raise	50	x 10	75	x 10	75	x 10	75	x 10
Bench Press	50	x 10	75	x 10	75	x 10	75	x 10
Lat. Pull Down	50	x 10	75	x 10	75	x 10	75	x 10
DB. Military	50	x 10	75	x 10	75	x 10	75	x 10
Barbell Curl	50	x 10	75	x 10	75	x 10	75	x 10

Abs:

Leg Press	Leg Curl	Calf	Bench	Lat. PD	DB. Military	Curl
400	*100*	*100*	*100*	*100*	*100*	*100*

Session # 2 Date: ______________

	Set # 1		Set # 2		Set # 3		Set # 4	
Leg Press	200	x 10	300	x 10	300	x 10	300	x 10
Leg Curl	50	x 10	75	x 10	75	x 10	75	x 10
Calf Raise	50	x 10	75	x 10	75	x 10	75	x 10
Bench Press	50	x 10	75	x 10	75	x 10	75	x 10
Lat. Pull Down	50	x 10	75	x 10	75	x 10	75	x 10
DB. Military	50	x 10	75	x 10	75	x 10	75	x 10
Barbell Curl	50	x 10	75	x 10	75	x 10	75	x 10

Abs:

Leg Press	Leg Curl	Calf	Bench	Lat. PD	DB. Military	Curl
400	*100*	*100*	*100*	*100*	*100*	*100*

Session # 3 Date: ______________

	Set # 1		Set # 2		Set # 3		Set # 4	

Leg Press	200	x 10	300	x 10	300	x 10	300	x 10
Leg Curl	50	x 10	75	x 10	75	x 10	75	x 10
Calf Raise	50	x 10	75	x 10	75	x 10	75	x 10
Bench Press	50	x 10	75	x 10	75	x 10	75	x 10
Lat. Pull Down	50	x 10	75	x 10	75	x 10	75	x 10
DB. Military	50	x 10	75	x 10	75	x 10	75	x 10
Barbell Curl	50	x 10	75	x 10	75	x 10	75	x 10
Abs:								

APPENDIX D

RAW DATA

Subj	Group	Time	Age	Height	Weight	VO2maxr	VO2maxa	BodyFath	BodyFats
1	ET	Pre	23	66	230	27.8	2.91	33.18	28.42
1	ET	Mid	23	66.5	227	32.4	3.34	31.84	27.98
1	ET	Post	23	67	221.5	36.3	3.65	30.9	27.12
2	ET	Pre	22	73.75	186	46.9	3.97	12.98	13.3
2	ET	Mid	22	74.5	188.5	49.2	4.22	13.57	12.79
2	ET	Post	22	75	195	46.3	4.10	14.72	14.74
3	ET	Pre	21	70.5	258.1	34.3	4.02	30.18	28.81
3	ET	Mid	21	72.5	249	35.1	3.97	27.38	27.88
3	ET	Post	21	72	246	37.2	4.16	27.35	27.81
4	ET	Pre	34	65	128	33.7	1.96	25	21.71
4	ET	Mid	34	65.5	130	36.5	2.16	24.45	20.87
4	ET	Post	34	65.5	128	37	2.15	24.17	21.6
5	ET	Pre	23	70.25	187	37.2	3.16	15.63	18.7
5	ET	Mid	23	70	183	43.7	3.64	15.36	16.49
5	ET	Post	24	71	182.5	44.9	3.72	14.52	15.8
6	ET	Pre	26	71.5	181	47.9	3.94	10.68	16.34
6	ET	Mid	26	72	183.5	47	3.92	13.16	15.14
6	ET	Post	26	71	182.5	46.1	3.82	12.81	16.16
7	ET	Pre	24	68	171.5	49.3	3.84	14.63	17.22
7	ET	Mid	24	67.75	166.5	52.6	3.98	12.66	13.74
7	ET	Post	25	67.5	168	53.3	4.07	11.25	14.25
8	ET	Pre	19	73	156	57.3	4.06	7.69	12.31
8	ET	Mid	19	73	161.5	54.6	4.01	8.02	11.5
8	ET	Post	20	73	162	54.7	4.03	6.72	11.75
9	ET	Pre	24	75	244	33.3	3.69	37.43	31.31
9	ET	Mid	24	74.5	245.5	34.1	3.81	35.28	29.79
9	ET	Post	24	75	239.5	35.9	3.91	33.8	28.94
10	ET	Pre	23	70.75	206	44	4.12	20.65	23.83
10	ET	Mid	24	70.5	203	53.5	4.94	19.01	20.95
10	ET	Post	24	70.5	199.5	51.1	4.63	17.81	21.22
11	ET	Pre	35	66.5	196	31.2	2.78	.	28.84
11	ET	Mid	35	66.5	194	36	3.17	.	26.94
11	ET	Post	35	66.5	193	39.1	3.43	.	28.68
12	ET	Pre	25	68.5	181	46.4	3.82	17.51	18.23
12	ET	Mid	25	69	179	45.6	3.71	16.31	15.47
12	ET	Post	25	68.5	179.5	49.6	4.05	15.6	11.78
13	RT	Pre	21	69.25	177.5	41.1	3.32	15.8	20.04
13	RT	Mid	21	69.25	182.5	39.5	3.28	15.2	17.94
13	RT	Post	21	70	183.5	42.1	3.51	14.52	19.54
14	RT	Pre	18	65.5	128	49.8	2.90	15.6	14.15
14	RT	Mid	18	65.5	133	47.3	2.86	14.73	17.88
14	RT	Post	18	66	144.5	47.1	3.09	18.63	19.85
15	RT	Pre	26	67.25	189.5	38.4	3.31	27.53	27.61

15	RT	Mid	26	67	197	35.6	3.19	29.1	25.57
15	RT	Post	26	67	195	35.3	3.13	29.04	26.75
16	RT	Pre	22	67.5	149	50	3.39	14.42	19.33
16	RT	Mid	22	68	151	47.7	3.27	14.12	17.94
16	RT	Post	22	68	150.5	47.7	3.26	14.13	20
17	RT	Pre	27	73	204	40.3	3.74	18.79	20.93
17	RT	Mid	27	74	206.5	39.6	3.72	18.17	19.11
17	RT	Post	27	74	211	41.4	3.97	18.92	19.69
18	RT	Pre	19	68	124	53.5	3.02	8.27	8.51
18	RT	Mid	20	68	133	51.3	3.10	9.36	9.19
18	RT	Post	20	68	132	51.7	3.10	8.39	9.68
19	RT	Pre	23	67.25	184.25	47.4	3.97	15.23	16.98
19	RT	Mid	23	67.5	186	45.5	3.85	14.73	15.11
19	RT	Post	23	68	188	46.1	3.94	13.66	16.79
20	RT	Pre	19	71	181.5	44.6	3.68	13.29	14.01
20	RT	Mid	20	71	179	43.8	3.56	11.05	11.41
20	RT	Post	20	72	181	45.2	3.72	11.32	12.75
21	RT	Pre	28	68	135.5	41.9	2.58	.	14.79
21	RT	Mid	28	68	138	41.9	2.63	.	16.14
21	RT	Post	28	68	140.5	44.1	2.82	.	16.83
22	RT	Pre	22	68.75	142.5	48.5	3.14	18.7	16
22	RT	Mid	22	68.5	141	47.8	3.06	18	13.32
22	RT	Post	22	69	145	50.8	3.35	18.08	16.31
23	RT	Pre	25	69	162.5	37.6	2.78	15.25	15.41
23	RT	Mid	25	69	166	44.3	3.34	14.37	13.13
23	RT	Post	25	69	163.5	47.3	3.52	11.89	12.66
24	RT	Pre	24	66.75	136	40.1	2.48	12.35	9.5
24	RT	Mid	24	67	143	43.1	2.80	12.92	10.35
24	RT	Post	24	67	145	46	3.03	11.55	10.98
25	RT	Pre	19	72	171	47.7	3.71	14.96	11.16
25	RT	Mid	19	72	170	43.6	3.37	13.13	12.64
25	RT	Post	19	72	174	39.1	3.09	12.82	12.44
26	CT	Pre	21	66.75	136	39.9	2.47	14.78	9.3
26	CT	Mid	21	66.5	139	44.7	2.82	13.37	8.95
26	CT	Post	21	67	140	49.1	3.12	13.82	10.7
27	CT	Pre	21	74.5	189	49.7	4.27	11.2	11.25
27	CT	Mid	21	74.5	196.5	49.9	4.46	11.98	12
27	CT	Post	22	75	198.5	54.6	4.93	11.22	13.25
28	CT	Pre	18	71.25	248	34	3.83	25.11	27.59
28	CT	Mid	18	71	245	39.6	4.41	22.92	24.92
28	CT	Post	18	71	238	39.1	4.23	20.9	24.46
29	CT	Pre	19	74.5	172.5	51.1	4.01	9.2	9.71
29	CT	Mid	19	74	181	50.4	4.15	9.67	8.94
29	CT	Post	20	74	182	51.7	4.28	10.05	9.61
30	CT	Pre	26	70.5	253	37.3	4.29	28.1	26.4
30	CT	Mid	26	71.5	256.5	34.9	4.07	25.88	26.36
30	CT	Post	26	71	257.5	37.1	4.34	26.48	27.41
31	CT	Pre	23	71.5	180.5	52.2	4.28	12.96	15.68
31	CT	Mid	23	72	182	48.3	4.00	11.78	15.87
31	CT	Post	24	71.5	182	48.4	4.00	11.61	15.67

32	CT	Pre	24	70	247.5	33.1	3.72	32.24	28.36
32	CT	Mid	24	70	242	36.2	3.98	29.93	28.1
32	CT	Post	24	70	242.5	36.7	4.05	29.59	27.8
33	CT	Pre	19	72.5	214	44.7	4.35	17.84	20.57
33	CT	Mid	19	73	220.5	41.7	4.18	17.27	20.89
33	CT	Post	20	73	217.5	37.8	3.74	17.87	22.15
34	CT	Pre	22	71	160	49.5	3.60	9.19	8.71
34	CT	Mid	22	71.5	165.5	49.7	3.74	7.71	10.47
34	CT	Post	23	71.5	168	49.1	3.75	7.98	10.45
35	CT	Pre	21	73.5	228.5	44.6	4.63	27.83	24.5
35	CT	Mid	21	73.5	223.5	44.2	4.49	27.19	24.18
35	CT	Post	21	73	238	37.7	4.08	28.8	25.53
36	CT	Pre	21	71.5	180.5	55.7	4.57	7.27	11.59
36	CT	Mid	21	72	184	54.8	4.58	7.38	10.77
36	CT	Post	21	72	187	54.3	4.62	7.33	12.4
37	CT	Pre	21	73.25	214	49.8	4.84	14.48	15.57
37	CT	Mid	22	73	210	46.7	4.46	13.82	16
37	CT	Post	22	73	213	50.1	4.85	13.3	17.28
38	CT	Pre	21	69	199	43.3	3.92	20.05	19.77
38	CT	Mid	21	69.75	204	43	3.99	17.3	18.69
38	CT	Post	21	70	204.5	41.9	3.89	17.82	19.54
39	CT	Pre	22	74	218.5	41.5	4.12	17.56	21.51
39	CT	Mid	22	74	213	43.1	4.17	14.37	19.72
39	CT	Post	22	74.5	213	43.3	4.19	15.64	20.27
40	CT	Pre	19	72.5	144	45.4	2.97	8.84	6.33
40	CT	Mid	19	73	152	48.7	3.36	5.87	6.7
40	CT	Post	19	73	155	47.9	3.37	4.6	7.86
41	CT	Pre	25	69	245.5	32.4	3.62	35.71	28.34
41	CT	Mid	25	69.25	241.5	33.4	3.67	35.92	28.19
41	CT	Post	25	69	243.5	34.7	3.84	35.34	27.53

Subj	Group	Time	StReach	JTouch	Vert	Dash	1RMLP	1RMBP
1	ET	Pre	89.5	107.5	18	5.77	720	180
1	ET	Mid	90.5	108.5	18	6.13	720	170
1	ET	Post	89.5	108.5	19	5.87	830	175
2	ET	Pre	101	121.5	20.5	5.52	500	160
2	ET	Mid	101.5	121	19.5	5.73	540	180
2	ET	Post	101.5	121	19.5	5.56	565	180
3	ET	Pre	96	114	18	5.66	720	210
3	ET	Mid	96	115	19	5.97	700	210
3	ET	Post	96	113.5	17.5	5.59	855	210
4	ET	Pre	88	104	16	5.87	230	85
4	ET	Mid	88	103.5	15.5	5.96	260	95
4	ET	Post	88.5	104	15.5	5.95	310	85
5	ET	Pre	95.5	116.5	21	5.7	540	160
5	ET	Mid	96.5	116.5	20	5.52	650	155
5	ET	Post	95.5	116.5	21	5.55	670	170
6	ET	Pre	94.5	117.5	23	5.19	770	240
6	ET	Mid	95	118.5	23.5	5.18	720	220

6	ET	Post	95	117	22	5.23	810	230
7	ET	Pre	88	107.5	19.5	5.24	630	235
7	ET	Mid	88	108.5	20.5	5.43	740	220
7	ET	Post	88.5	110	21.5	5.14	770	230
8	ET	Pre	97	120	23	4.92	510	140
8	ET	Mid	97.5	121	23.5	4.89	600	155
8	ET	Post	97.5	122.5	25	4.93	610	180
9	ET	Pre	99	113.5	14.5	6.61	520	115
9	ET	Mid	98	114	16	6.53	520	115
9	ET	Post	99	114	15	.	540	.
10	ET	Pre	94	111	17	5.51	720	210
10	ET	Mid	93.5	111.5	18	5.57	900	210
10	ET	Post	94	111.5	17.5	5.46	950	220
11	ET	Pre	90.5	103.5	13	5.81	630	140
11	ET	Mid	90.5	104.5	14	6.29	720	140
11	ET	Post	90	105	15	6.21	830	160
12	ET	Pre	91.5	113	21.5	5.29	650	210
12	ET	Mid	92.5	114	21.5	5.33	700	210
12	ET	Post	91.5	115	23.5	5.2	860	215
13	RT	Pre	90.5	111	20.5	5.03	600	150
13	RT	Mid	92	112.5	20.5	5.12	715	175
13	RT	Post	92	114.5	22.5	5.21	850	205
14	RT	Pre	87.5	106	18.5	5.69	350	85
14	RT	Mid	87.5	104.5	17	5.92	450	110
14	RT	Post	88.5	106	17.5	5.79	465	130
15	RT	Pre	90	105.5	15.5	5.69	470	160
15	RT	Mid	90	104.5	14.5	5.9	610	190
15	RT	Post	90.5	105	14.5	6.16	770	215
16	RT	Pre	92	110.5	18.5	5.68	470	160
16	RT	Mid	92	112.5	20.5	5.41	490	180
16	RT	Post	92	113	21	5.54	640	200
17	RT	Pre	98.5	118.5	20	5.95	410	200
17	RT	Mid	98.5	119.5	21	5.89	510	220
17	RT	Post	99	120	21	5.81	585	240
18	RT	Pre	90	114	24	5.53	380	80
18	RT	Mid	90	114.5	24.5	5.59	500	110
18	RT	Post	90.5	113	22.5	5.54	625	125
19	RT	Pre	91	113.5	22.5	5.22	600	185
19	RT	Mid	90	114.5	24.5	5.04	780	215
19	RT	Post	90.5	113.5	23	5.25	805	220
20	RT	Pre	95.5	115	19.5	5.49	710	210
20	RT	Mid	96	118.5	22.5	5.45	740	235
20	RT	Post	96	118.5	22.5	5.66	900	240
21	RT	Pre	91.5	110	18.5	5.9	400	95
21	RT	Mid	91	111	20	5.81	460	135
21	RT	Post	91.5	112	20.5	5.84	540	155
22	RT	Pre	93	116.5	23.5	5.4	450	105
22	RT	Mid	93.5	116	22.5	5.49	500	120
22	RT	Post	93.5	117.5	24	5.5	520	140
23	RT	Pre	92	110	18	5.8	480	190

23	RT	Mid	90	112.5	22.5	5.55	630	210
23	RT	Post	89.5	113.5	24	5.23	700	230
24	RT	Pre	90	114	24	5.18	540	145
24	RT	Mid	91	116	25	5.41	680	170
24	RT	Post	90.5	117.5	27	5.13	835	200
25	RT	Pre	97.5	118.5	21	5.25	470	135
25	RT	Mid	97.5	118	20.5	5.68	540	160
25	RT	Post	97.5	118	20.5	5.58	680	180
26	CT	Pre	88.5	107.5	19	6.02	500	140
26	CT	Mid	89	108.5	19.5	5.85	540	175
26	CT	Post	88.5	109	20.5	5.75	610	180
27	CT	Pre	100	124.5	24.5	5.53	560	150
27	CT	Mid	100	126	26	5.61	650	180
27	CT	Post	101	127	26	5.37	735	190
28	CT	Pre	98	115	17	6.03	630	230
28	CT	Mid	98.5	115.5	17	5.78	720	270
28	CT	Post	98	115	17	5.82	855	290
29	CT	Pre	99.5	119.5	20	5.57	520	170
29	CT	Mid	101	120	19	5.64	630	205
29	CT	Post	100.5	120.5	20	5.71	720	235
30	CT	Pre	98	114	16	5.89	720	180
30	CT	Mid	98	113.5	15.5	6.29	950	190
30	CT	Post	98	113	15	6.35	1080	210
31	CT	Pre	96	117	21	4.96	540	140
31	CT	Mid	96	117	21	5.24	600	170
31	CT	Post	96	118	22	5.08	750	190
32	CT	Pre	95.5	110.5	15	6.07	700	160
32	CT	Mid	96	110	14	6.25	900	200
32	CT	Post	95.5	110.5	15	5.88	1010	220
33	CT	Pre	95	118.5	23.5	4.96	700	190
33	CT	Mid	97	119	22	5.17	900	230
33	CT	Post	97	118	21	5.22	925	230
34	CT	Pre	94	119	25	5.3	630	170
34	CT	Mid	94	121	27	5.25	680	210
34	CT	Post	94	121	27	5.15	765	230
35	CT	Pre	99.5	116	16.5	5.78	470	130
35	CT	Mid	100	115.5	15.5	5.93	630	150
35	CT	Post	99.5	115	15.5	6.08	760	160
36	CT	Pre	93.5	118.5	25	5.23	680	185
36	CT	Mid	95.5	119.5	24	5.25	810	210
36	CT	Post	96	120	24	5.25	945	210
37	CT	Pre	96.5	122.5	26	4.98	720	300
37	CT	Mid	96.5	123	26.5	5.14	1015	310
37	CT	Post	97.5	123	25.5	5.04	1100	315
38	CT	Pre	91	114.5	23.5	5.29	880	200
38	CT	Mid	91	114.5	23.5	5.27	1090	220
38	CT	Post	91	114	23	5.25	1170	230
39	CT	Pre	99	119	20	5.46	590	230
39	CT	Mid	100	118.5	18.5	5.59	750	210
39	CT	Post	99.5	119	19.5	5.62	800	230

40	CT	Pre	96	119.5	23.5	5.44	480	140
40	CT	Mid	96	120	24	5.13	650	160
40	CT	Post	96	120	24	5.03	700	185
41	CT	Pre	93.5	104	10.5	6.81	470	180
41	CT	Mid	93	104	11	7.02	600	190
41	CT	Post	93	104.5	11.5	6.87	720	205

			60°/second			
Subj	**Group**	**Time**	**PText60**	**PTflx60**	**AvPext60**	**AvPflx60**
1	ET	Pre	201.6	95.9	110.7	73.3
1	ET	Mid	.	.	.	.
1	ET	Post	185.1	88.3	118.1	74
2	ET	Pre	168.9	100.6	100.5	70.7
2	ET	Mid	.	.	.	.
2	ET	Post	184	102	117	75.8
3	ET	Pre	211.2	105.6	107.4	78.4
3	ET	Mid	.	.	.	.
3	ET	Post	183	82.7	97.7	52.6
4	ET	Pre	98.5	40.4	49.4	23.1
4	ET	Mid	.	.	.	.
4	ET	Post	88	34.4	48	20.8
5	ET	Pre	182.7	79.8	106.9	63.7
5	ET	Mid	.	.	.	.
5	ET	Post	161.6	72.1	98.1	48.3
6	ET	Pre	196.4	88.4	109	55.8
6	ET	Mid	.	.	.	.
6	ET	Post	164.5	71.3	92.5	51.3
7	ET	Pre	118.9	67.6	75.2	47.4
7	ET	Mid	.	.	.	.
7	ET	Post	168.6	81.9	91	61.4
8	ET	Pre	119.8	51.2	62.8	22.2
8	ET	Mid	.	.	.	.
8	ET	Post	138.8	78.8	73.6	56.4
9	ET	Pre	135.5	61	86	46.2
9	ET	Mid	.	.	.	.
9	ET	Post	149.5	63.2	100.7	50.4
10	ET	Pre	201.9	117	103.8	87
10	ET	Mid	.	.	.	.
10	ET	Post	156.1	98.7	97.2	57.4
11	ET	Pre	128.7	80.5	74.8	48.1
11	ET	Mid	.	.	.	.
11	ET	Post	133.1	79.9	75.5	57.6
12	ET	Pre	143	70	87.4	57.2
12	ET	Mid	.	.	.	.
12	ET	Post	147.7	70.1	91.6	46
13	RT	Pre	139.5	73.1	76.1	47.4
13	RT	Mid	.	.	.	.
13	RT	Post	143.9	78.4	80.5	60.3
14	RT	Pre	116	69.4	69	49.9

14	RT	Mid	.	.	.	.
14	RT	Post	115.8	66.5	72.7	51.8
15	RT	Pre	127.8	49.8	68	34.8
15	RT	Mid	.	.	.	.
15	RT	Post	126.8	77.8	68.3	43.6
16	RT	Pre	125.3	59.9	68.3	48.2
16	RT	Mid	.	.	.	.
16	RT	Post	136.1	81.7	75.6	62.5
17	RT	Pre	94.8	65.8	49.6	40.2
17	RT	Mid	.	.	.	.
17	RT	Post	88.2	67	48.9	47.3
18	RT	Pre	110.2	59	52.1	44.1
18	RT	Mid	.	.	.	.
18	RT	Post	100.3	61.3	55.1	43.9
19	RT	Pre	125.1	92.9	77.4	67.4
19	RT	Mid	.	.	.	.
19	RT	Post	141.3	99.1	74.8	75
20	RT	Pre	192.4	100.5	111.1	70
20	RT	Mid	.	.	.	.
20	RT	Post	203.7	91.6	120.7	70.9
21	RT	Pre	147.9	74.7	88.2	52.1
21	RT	Mid	.	.	.	.
21	RT	Post	100.4	66.8	56.8	47
22	RT	Pre	140.2	77.7	74.8	55.7
22	RT	Mid	.	.	.	.
22	RT	Post	135.6	73.5	71.4	57.7
23	RT	Pre	136.6	88.9	81.9	70.6
23	RT	Mid	.	.	.	.
23	RT	Post	137.2	89.5	83.6	71.6
24	RT	Pre	145.4	73	74.8	50.2
24	RT	Mid	.	.	.	.
24	RT	Post	157.2	90.7	94.9	64.3
25	RT	Pre	190.1	106.6	128.3	76.4
25	RT	Mid	.	.	.	.
25	RT	Post	180.6	105.4	108.3	82.4
26	CT	Pre	107.6	67.1	61.5	43.4
26	CT	Mid	.	.	.	.
26	CT	Post	111.7	67.6	68.5	51.9
27	CT	Pre	193.2	87.4	106.4	58.6
27	CT	Mid	.	.	.	.
27	CT	Post	204.1	104.1	113.4	74.6
28	CT	Pre	215.1	66.7	125.6	36.8
28	CT	Mid	.	.	.	.
28	CT	Post	215.5	83.6	118.9	56.4
29	CT	Pre	182.4	86.6	105.5	68.9
29	CT	Mid	.	.	.	.
29	CT	Post	155	63.7	96.3	49.1
30	CT	Pre	216.7	106.2	114.1	70.5
30	CT	Mid	.	.	.	.
30	CT	Post	184.8	101.1	101.7	64.5

31	CT	Pre	175	97.3	107.4	77.6
31	CT	Mid	.	.	.	.
31	CT	Post	166.7	88	97.9	71.9
32	CT	Pre	175.4	89.1	112.7	69.5
32	CT	Mid	.	.	.	.
32	CT	Post	199.1	90	111.9	68.8
33	CT	Pre	185.6	77.1	114.3	65.6
33	CT	Mid	.	.	.	.
33	CT	Post	168.6	111.8	103	74.1
34	CT	Pre	150.8	46.2	92.7	29.3
34	CT	Mid	.	.	.	.
34	CT	Post	158.5	89	101.6	66.1
35	CT	Pre	159.3	69.3	86.3	41.3
35	CT	Mid	.	.	.	.
35	CT	Post	146.2	67.9	85.6	48.9
36	CT	Pre	206.3	91.2	115.7	74.9
36	CT	Mid	.	.	.	.
36	CT	Post	182.3	90.8	98.4	77.8
37	CT	Pre	127.9	77.4	79.9	56.9
37	CT	Mid	.	.	.	.
37	CT	Post	152.9	89.6	93.5	70.1
38	CT	Pre	154.4	119.8	104.6	81
38	CT	Mid	.	.	.	.
38	CT	Post	148.6	117.9	85.5	79.1
39	CT	Pre	225.4	109.2	134.3	72.9
39	CT	Mid	.	.	.	.
39	CT	Post	189.4	101.7	95.4	71.6
40	CT	Pre	156.6	73.7	91	53.3
40	CT	Mid	.	.	.	.
40	CT	Post	139.4	86.9	82.5	70
41	CT	Pre	.	.	.	.
41	CT	Mid	.	.	.	.
41	CT	Post	.	.	.	.

			180°/second			
Subj	**Group**	**Time**	**PText180**	**PTflx180**	**APext180**	**APflx180**
1	ET	Pre	130	69.5	198.5	114.8
1	ET	Mid	.	.	.	.
1	ET	Post	123.7	76.1	173.5	113.6
2	ET	Pre	113.1	68.2	164.2	112.9
2	ET	Mid	.	.	.	.
2	ET	Post	117.5	69.9	171.9	101.3
3	ET	Pre	142.7	73.3	223.6	108.2
3	ET	Mid	.	.	.	.
3	ET	Post	142.3	69.2	217.6	113.4
4	ET	Pre	67.8	36.5	100.2	47.1
4	ET	Mid	.	.	.	.
4	ET	Post	66.3	28.8	88.8	39.3
5	ET	Pre	100.3	59	161.6	74.7

5	ET	Mid	.	.	.	.
5	ET	Post	101.6	49.3	158.1	78.2
6	ET	Pre	103.8	55	155.8	86.9
6	ET	Mid	.	.	.	.
6	ET	Post	106.1	45.8	155.6	64.1
7	ET	Pre	105.5	64.6	168.1	109.4
7	ET	Mid	.	.	.	.
7	ET	Post	118.9	70.3	169.5	107.2
8	ET	Pre	104.5	46.8	156.3	53.8
8	ET	Mid	.	.	.	.
8	ET	Post	114.4	46.9	172.6	55.1
9	ET	Pre	77.5	36.6	111.7	45.5
9	ET	Mid	.	.	.	.
9	ET	Post	90.1	42.7	135.2	52.9
10	ET	Pre	122.8	81.7	186.6	122.6
10	ET	Mid	.	.	.	.
10	ET	Post	127	73.9	200.7	99.5
11	ET	Pre	81.2	54.5	132.4	80.6
11	ET	Mid	.	.	.	.
11	ET	Post	92.2	54.4	123.4	88.4
12	ET	Pre	102.2	53.2	165.9	82.7
12	ET	Mid	.	.	.	.
12	ET	Post	117.8	62.7	158.7	88.7
13	RT	Pre	101	52.6	165.4	91.1
13	RT	Mid	.	.	.	.
13	RT	Post	113.2	54.2	176.6	84.5
14	RT	Pre	81	48.6	113.2	79.6
14	RT	Mid	.	.	.	.
14	RT	Post	88.7	54.6	132.1	86.5
15	RT	Pre	89.5	39.5	145.8	52.2
15	RT	Mid	.	.	.	.
15	RT	Post	94.9	55.6	146.4	83
16	RT	Pre	95.2	54.9	149.8	89.3
16	RT	Mid	.	.	.	.
16	RT	Post	93.1	58	134.4	93.5
17	RT	Pre	79.2	44.5	90.6	38.7
17	RT	Mid	.	.	.	.
17	RT	Post	72.7	52.7	87.2	79.3
18	RT	Pre	66	43.2	98.8	67.8
18	RT	Mid	.	.	.	.
18	RT	Post	82.6	42.7	124	64.3
19	RT	Pre	115.7	76.7	186.3	128.3
19	RT	Mid	.	.	.	.
19	RT	Post	129.3	78	189.1	114.6
20	RT	Pre	121	63.5	184	103.7
20	RT	Mid	.	.	.	.
20	RT	Post	142.8	67.5	228	109.7
21	RT	Pre	56.6	37.8	81.5	23.6
21	RT	Mid	.	.	.	.
21	RT	Post	64.1	39.2	88.8	46.3

22	RT	Pre	109	62.2	149.6	95.7
22	RT	Mid	.	.	.	.
22	RT	Post	112.8	64.2	163.7	93.2
23	RT	Pre	86.1	60.7	147	109.6
23	RT	Mid	.	.	.	.
23	RT	Post	99.8	72.3	150.7	132.8
24	RT	Pre	88.3	52.9	110.9	88.3
24	RT	Mid	.	.	.	.
24	RT	Post	120.1	75.5	179	120.7
25	RT	Pre	129.5	77.2	219.5	133.7
25	RT	Mid	.	.	.	.
25	RT	Post	130.5	79.1	192.9	119
26	CT	Pre	84.7	50.2	143.3	72.9
26	CT	Mid	.	.	.	.
26	CT	Post	91.7	55.5	131.6	70.6
27	CT	Pre	130.9	65.4	189.7	85.6
27	CT	Mid	.	.	.	.
27	CT	Post	124.7	60.7	182.5	92.5
28	CT	Pre	132.2	67.8	202.8	79.6
28	CT	Mid	.	.	.	.
28	CT	Post	134.3	37.5	203.4	47.1
29	CT	Pre	105	63.1	178.8	94.9
29	CT	Mid	.	.	.	.
29	CT	Post	111	53.3	177.1	77.7
30	CT	Pre	134.6	84.7	229.1	120.4
30	CT	Mid	.	.	.	.
30	CT	Post	117.6	76.3	180.9	101.3
31	CT	Pre	101.2	70.2	172.8	122
31	CT	Mid	.	.	.	.
31	CT	Post	100.4	62.2	151.8	103.6
32	CT	Pre	120.8	64.7	184.8	103.8
32	CT	Mid	.	.	.	.
32	CT	Post	128.1	63.7	193.3	103.3
33	CT	Pre	149.1	73.4	249.2	134.4
33	CT	Mid	.	.	.	.
33	CT	Post	135.5	67.2	220.4	106.1
34	CT	Pre	115.1	65.8	181.6	98.7
34	CT	Mid	.	.	.	.
34	CT	Post	134.3	70.8	215.7	115.2
35	CT	Pre	108.5	61.9	160.3	87.5
35	CT	Mid	.	.	.	.
35	CT	Post	122.1	60.2	168.9	78.6
36	CT	Pre	134	76.6	201.7	116.8
36	CT	Mid	.	.	.	.
36	CT	Post	128.4	82	188.3	126.9
37	CT	Pre	112.3	63.9	150.3	73.9
37	CT	Mid	.	.	.	.
37	CT	Post	130.8	73.1	187.4	104.5
38	CT	Pre	138.2	89.9	229.2	137.6
38	CT	Mid	.	.	.	.

38	CT	Post	122.6	87.7	190.7	115.6
39	CT	Pre	151.2	70.5	208	79.7
39	CT	Mid	.	.	.	.
39	CT	Post	119.5	71.6	153.8	74.8
40	CT	Pre	96.1	58.2	137.7	78
40	CT	Mid	.	.	.	.
40	CT	Post	111.9	57.1	163.2	97.9
41	CT	Pre	.	.	.	.
41	CT	Mid	.	.	.	.
41	CT	Post	.	.	.	.

Raw Data Key:

Subj = Subject

Group = Training group

Time = Time of testing

Height = Height (inches)

Weight = Weight (pounds)

VO2maxr = Relative maximal oxygen consumption (ml/kg/min)

VO2maxa = Absolute maximal oxygen consumption (L/min)

BodyFath = Percent body fat (measured hydrostatically)

BodyFats = Percent body fat (measured by sum of seven skin fold)

StReach = Standing reach (inches)

JTouch = Jump touch (inches)

Vert = Vertical Jump (inches)

Dash = 40-yard dash time (seconds)

1RMLP = One repetition maximum leg press (pounds)

1RMBP = One repetition maximum bench press (pounds)

PText60 = Peak torque during extension at 60 degrees per second

PTflx60 = Peak torque during flexion at 60 degrees per second

AvPext60 = Average power during extension at 60 degrees per second

AvPflx60 = Average power during flexion at 60 degrees per second

PText180 = Peak torque during extension at 180 degrees per second

PTflx180 = Peak torque during flexion at 180 degrees per second

APext180 = Average power during extension at 180 degrees per second

APflx180 = Average power during flexion at 180 degrees per second

APPENDIX E

STATISTICAL CODE

```
DATA SG1;
INPUT Name $ subj Group $ WeightPR WeightPO VO2rPR VO2rPO VO2aPR
VO2aPO BFathPR BFathPO;
CARDS;

DATA SG2;
INPUT BFatsPR BFatsPO VertPR VertPO DashPR DashPO RMLPPR RMLPPO
RMBPPR RMBPPO;
CARDS;

DATA SG3;
INPUT PTex60PR PTex60PO PTfl60PR PTfl60PO APex60PR APex60PO APfl60PR
APfl60PO PTe180PR PTe180PO;
CARDS;
DATA SG4;
INPUT PTf180PR PTf180PO APe180PR APe180PO APf180PR APf180PO;
CARDS;
DATA SG;
MERGE SG1 SG2 SG3 SG4;
DWEIGHT = WEIGHTPO - WEIGHTPR;
DVO2R = VO2rPO - VO2rPR;
DVO2A = VO2aPO - VO2aPR;
DBFATH = BFATHPO - BFATHPR;
DBFATS = BFATSPO - BFATSPR;
DVERT = VERTPO - VERTPR;
DDASH = DASHPO - DASHPR;
DRMLP = RMLPPO - RMLPPR;
DRMBP = RMBPPO - RMBPPR;
DPTEX60 = PTEX60PO - PTEX60PR;
DPTFL60 = PTFL60PO - PTFL60PR;
DAPEX60 = APEX60PO - APEX60PR;
DAPFL60 = APFL60PO - APFL60PR;
DPTE180 = PTE180PO - PTE180PR;
DPTF180 = PTF180PO - PTF180PR;
DAPE180 = APE180PO - APE180PR;
DAPF180 = APF180PO - APF180PR;

PROC SORT;
BY GROUP;
```

```
PROC MEANS MAXDEC=2 MEAN STD T PRT;
BY GROUP;
VAR DWEIGHT DVO2R DVO2A DBFATH DBFATS DVERT DDASH DRMLP
DRMBP DPTEX60 DPTFL60
DAPEX60 DAPFL60 DPTE180 DPTF180 DAPE180 DAPF180;

PROC ANOVA;
CLASS GROUP;
MODEL DWEIGHT DVO2R DVO2A DBFATH DBFATS DVERT DDASH DRMLP
DRMBP DPTEX60 DPTFL60
DAPEX60 DAPFL60 DPTE180 DPTF180 DAPE180 DAPF180 = GROUP;
MEANS GROUP / DUNCAN;

RUN;
QUIT;




DATA SS1;
INPUT Name $ Subj $ Group $ Time $ Age Height Weight;
CARDS;
DATA SS2;
INPUT  VO2maxr  VO2maxa BodyFath BodyFats StReach   JTouch  Vert Dash
ONERMLP ONERMBP;
CARDS;

DATA SS3;
INPUT PText60 PTflx60   AvPext60 AvPflx60 PText180 PTflx180 APext180 APflx180;
CARDS;

DATA SSALL;
MERGE SS1 SS2 SS3;

*3 X 3 REPEATED MEASURES DESIGN**;
PROC GLM;
TITLE 'GROUP (3) X TIME (3) ANALYSIS WITH
REPATED MEASURES ACROSS TIME';
CLASS SUBJ GROUP TIME;
MODEL WEIGHT VO2MAXR VO2MAXA BODYFATS BODYFATH STREACH
JTOUCH VERT DASH ONERMLP ONERMBP
      PText60 PTflx60 AvPext60 AvPflx60 PText180 PTflx180 APext180 APflx180
      = GROUP SUBJ(GROUP) TIME GROUP*TIME TIME*SUBJ(GROUP);
MEANS GROUP | TIME;
TEST H=GROUP E=SUBJ(GROUP);
TEST H=TIME GROUP*TIME E=TIME*SUBJ(GROUP);
```

```
MEANS GROUP / E=SUBJ(GROUP) DUNCAN;
MEANS TIME GROUP*TIME / E=TIME*SUBJ(GROUP) DUNCAN;



*PROC TRANSPOSE DATA = SSALL OUT = SSALLOUT;


**WITHIN GROUP ANALYSIS FOR ET**;
*TITLE 'WITHING GROUP FOR ET';
*DATA ET;
*SET SSALL;
*IF GROUP = 'RT' THEN DELETE;
*IF GROUP = 'CT' THEN DELETE;
*PROC ANOVA;
*CLASS SUBJ TIME;
*MODEL WEIGHT VO2MAXR VO2MAXA BODYFATS BODYFATH STREACH
JTOUCH VERT DASH ONERMLP ONERMBP
    PText60 PTflx60 AvPext60 AvPflx60 PText180 PTflx180 APext180 APflx180
    = SUBJ TIME;
*MEANS TIME /DUNCAN;
*PROC SORT;
*BY TIME;
*PROC MEANS MAXDEC=2;
*BY TIME;


**WITHIN GROUP ANALYSIS FOR CT**;
*TITLE 'WITHING GROUP FOR CT';
*DATA CT;
*SET SSALL;
*IF GROUP = 'RT' THEN DELETE;
*IF GROUP = 'ET' THEN DELETE;
*PROC ANOVA;
*CLASS SUBJ TIME;
*MODEL WEIGHT VO2MAXR VO2MAXA BODYFATS BODYFATH STREACH
JTOUCH VERT DASH ONERMLP ONERMBP
    PText60 PTflx60 AvPext60 AvPflx60 PText180 PTflx180 APext180 APflx180
    = SUBJ TIME;
*MEANS TIME /DUNCAN;
*PROC SORT;
*BY TIME;
*PROC MEANS MAXDEC=2;
*BY TIME;
```

```
**WITHIN GROUP ANALYSIS FOR RT**;
*TITLE 'WITHING GROUP FOR RT';
*DATA RT;
*SET SSALL;
*IF GROUP = 'CT' THEN DELETE;
*IF GROUP = 'ET' THEN DELETE;
*PROC ANOVA;
*CLASS SUBJ TIME;
*MODEL WEIGHT VO2MAXR VO2MAXA BODYFATS BODYFATH STREACH
JTOUCH VERT DASH ONERMLP ONERMBP
      PText60 PTflx60 AvPext60 AvPflx60 PText180 PTflx180 APext180 APflx180
      = SUBJ TIME;
*MEANS TIME /DUNCAN;
*PROC SORT;
*BY TIME;
*PROC MEANS MAXDEC=2;
*BY TIME;



Run;
Quit;
```

VITA

SHAWN PHILIP GLOWACKI

Place and Date of Birth: Houston, Texas, March 28, 1978.

Schools Attended and Degrees Conferred

B.S. Kinesiology (Applied Exercise Physiology)

Texas A&M University, College Station, Texas. December 2001.

M.S. Kinesiology (Exercise Physiology)

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Professional Experience

Student Assistant: Texas A&M Strength and Conditioning, 2000-2002

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